DETERMINANTS, MECHANISMS, AND ASSOCIATION OF WATER INSECURITY WITH HIV TREATMENT OUTCOMES AMONG ADULTS ON ANTIRETROVIRAL THERAPY IN KISUMU COUNTY, KENYA

BY

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DECLARATION

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

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DEDICATION

To my children: Terri-Jenn and Jeff-Trevor, my motivation

To my husband, Tom Abol, my pillar of support

To my brothers, Claydon Ayub, Dr. Bell Okello, Major Kwach, and Nixon Khama, my inspiration

To my late parents, Dr. H. Odak Ayub and T.A. Odak, you ignited the desire to work in health

To my late sister Keziah, to my late brother Omondi, you lit the fire to investigate;

AND

To all PWH,

THE SOLUTION EXISTS...

ABSTRACT

Despite progress in HIV management, resource insecurities threaten the gains made with antiretroviral therapy (ART) among adults globally. Water insecurity, a common problem in high HIV burden regions, has not received much attention despite its important role in HIV treatment outcomes. Kisumu County has a high HIV prevalence (11.7%), a 17% viral suppression gap, and only 42% water access, however, the relationship of water insecurity with HIV outcomes among ART clients is not adequately understood. This study, in line with the Sustainable Development Goals (SDGs) 3 and 6, had the general objective of establishing the determinants, the mechanisms, and the association of water insecurity with HIV treatment outcomes among adults on ART in Kisumu County. The specific objectives were 1) to estimate the prevalence and characterize the drivers and dimensions of water insecurity; 2) to explore the lived experiences of water insecurity and elucidate pathways from water insecurity to HIV treatment outcomes, and 3) to determine the association of water insecurity with HIV treatment outcomes among adults on ART and assess whether sex modified this association. An integrated multiphase mixed-methods design was employed. In Phase I, a baseline cross-sectional study of 434 randomly selected adults addressed the first objective, with a nested water quality sub-study. In Phase II, water insecure participants were purposively selected to explore the lived experiences of water insecurity. In Phase III, a matched case–control study of 356 randomly selected adults was conducted to determine the association between water insecurity and HIV treatment outcomes and assess sex as an effect modifier. Quantitative data were analyzed using descriptive and inferential statistics ($\alpha = 0.05$). Qualitative data were analyzed using inductive thematic analysis, followed by framework analysis to develop a novel conceptual model. Baseline household water insecurity prevalence was 64%. Determinants of water insecurity included socio-structural factors, communal, and individual factors. Female sex (OR = 4.88; 95% CI: 3.11–7.67; $p < 0.001$; AOR = 3.65; 95% CI: 2.02–6.58; $p < 0.001$), and microbial contamination (OR = 10.04, 95% CI: 5.94–16.95, $p < 0.001$; AOR = 3.96, 95% CI: 2.07–7.59, $p < 0.001$) were independent predictors of water insecurity. Water sources had widespread microbial (76.5%) and physicochemical (94%) contamination. The lived experiences revealed challenges with availability, access and quality, resulting in HIV treatment interruptions. Physical health, psychosocial, resource insecurity, and water-dependent dosing mechanistic pathways linked water insecurity to HIV treatment outcomes. In the case–control study, water insecurity was strongly associated with poor HIV treatment outcomes (OR = 3.18, 95% CI: 1.95–5.17; $p <0.001$; AOR = 3.66, 95% CI: 2.13–6.29, $p < 0.001$), with no evidence that sex modified the association. Increasing severity of water insecurity was associated with higher odds of poor HIV treatment outcomes, with each 5-point increase in the water insecurity score doubling those odds (OR = 2.05, 95% CI 1.72–2.44; $p < 0.001$). Water insecurity was highly prevalent among adults on ART and increased the risk of poor HIV treatment outcomes. Multi-sectoral collaboration for strengthening water infrastructure, governance, and adaptive capacities may reduce water insecurity and downstream health impacts. Integrated patient-provider strategies can help sustain HIV care engagement despite structural barriers to treatment continuity. Institutionalization of water insecurity interventions within HIV care may mitigate its impact on HIV treatment outcomes in Kisumu County, while contributing to the global SDGs efforts of eradicating HIV.

TABLE OF CONTENTS

DECLARATION ..... **II**

ACKNOWLEDGEMENT ..... **III**

DEDICATION ..... **IV**

ABSTRACT ..... **V**

TABLE OF CONTENTS ..... **VI**

LIST OF ABBREVIATIONS AND ACRONYMS ..... **IX**

OPERATIONAL DEFINITION OF TERMS ..... **XI**

LIST OF TABLES ..... **XIII**

LIST OF FIGURES ..... **XIV**

CHAPTER ONE: INTRODUCTION **1**

1.1 Background to the Study 1
1.2 Statement of the problem 9
1.3 Research Objectives 10
1.3.1 General objective 10
1.3.2 Specific objectives 10
1.4 Research Questions 10
1.5 Hypotheses 10
1.6 Significance of the Study 11
1.7 Study Assumptions 12

CHAPTER TWO: LITERATURE REVIEW **14**

2.1 Socio-ecological determinants (drivers and dimensions) of water insecurity 14
2.1.1 Water insecurity: overview of burden and conceptual framing 14
2.1.2 The Socio-ecological Model 18
2.1.3 Socio-ecological drivers of water insecurity 20
2.1.4 Dimensions of water insecurity 34
2.2 Lived experience of water insecurity 38
2.2.1 The Capability Approach 41
2.3 Association between water insecurity and HIV treatment outcomes 43
2.3.1 Water insecurity in the context of the HIV global to local burden 43
2.3.2 Water insecurity and ART adherence 45
2.3.3 Water insecurity and HIV treatment outcomes 47
2.4 Gender and gendered differences in water insecurity and HIV burden 51
2.5 Food insecurity 52
2.6 Physical water-related illnesses 55
2.7 Mental health and well-being 56
2.8 A synthesis of plausible mechanisms linking water insecurity and HIV treatment outcomes 58
2.9 Summary of concepts 60
2.10 Conceptual Framework 62

CHAPTER THREE: MATERIALS AND METHODS **64**

3.1 Study area 64
3.1.2 Study setting 65

3.2 TARGET POPULATION 66
3.2.1 Study population 66
3.2.2 Accessible/Sample population 66
3.3 STUDY DESIGN 66
3.3.1 Phase I: Baseline cross-sectional survey 68
3.3.2 Phase II: Qualitative exploratory study 69
3.3.3 Phase III: Case-Control Study 69
3.3.4 Design rationale and justification 71
3.4 SAMPLING DESIGN 72
3.4.1 Sample size determination 72
3.4.2 Overall sampling procedure 75
3.5 PRE-TEST OF TOOLS 78
3.6 DATA COLLECTION 79
3.6.1 Data collection tools 79
3.6.2 Data collection procedures 82
3.6.3. Measurement of key variables 84
3.7 QUALITY ASSURANCE 87
3.7.1 Internal validity 87
3.7.2 External validity 92
3.8 DATA MANAGEMENT AND ANALYSIS 92
3.8.1 Specific objective 1 93
3.8.1.1: Baseline cross-sectional study 93
3.8.1.2 Water quality sub-study 94
3.8.2 Specific objective 2: Exploratory qualitative study 97
3.8.3 Specific objective 3: Case-control study 103
3.9 ETHICAL CONSIDERATIONS 106
3.10 DISSEMINATION OF RESEARCH FINDINGS 108

CHAPTER FOUR: RESULTS & FINDINGS 109

4.1 PARTICIPANT BASELINE SOCIODEMOGRAPHIC CHARACTERISTICS 109
4.2 PREVALENCE AND DISTRIBUTION OF WATER INSECURITY 112
4.3 SOCIO-ECOLOGICAL DRIVERS AND DIMENSIONS OF WATER INSECURITY 113
4.3.1 Perceived drivers of water insecurity 113
4.3.2 Perceived dimensions of water insecurity 114
4.3.3 Predictors of water insecurity among adults on ART 115
4.3.4 Microbiological and physicochemical water quality 119
4.3.4.1 Microbiological Quality of Water Sources 119
4.3.4.2 Physical and chemical quality water sources used by adults on ART 122
4.3.4.3 Summary of water quality analysis from sampled sources used by adults on ART i 124
4.4 THE LIVED EXPERIENCE OF WATER INSECURITY AND PATHWAYS TO HIV TREATMENT OUTCOMES 125
4.4.1 The lived experience of water insecurity among adults on ART in Kisumu County 126
4.4.2 Pathways from water insecurity to HIV treatment outcomes 144
4.5 THE ASSOCIATION OF WATER INSECURITY WITH HIV TREATMENT OUTCOMES AMONG ADULTS ON ART 147
4.5.1 Overall association between water insecurity and HIV treatment outcomes 149
4.5.2 The association between water insecurity severity and HIV treatment outcomes 151
4.5.3 Sex as a modifier of the association between water insecurity and HIV treatment outcomes 152
4.5.4 Predicted probabilities of poor HIV treatment outcomes by water insecurity and sex 153
4.5.5 Secondary analyses of intermediate variables 154
4.6 THE NOVEL CONCEPTUAL MODEL 156

CHAPTER FIVE: DISCUSSION 157

5.1 SOCIO-ECOLOGICAL DRIVERS AND DIMENSIONS OF WATER INSECURITY AMONG ADULTS ON ART 157
5.1.1 Sociodemographic characteristics of adults on ART 157
5.1.2 Prevalence and severity of household water insecurity 158
5.1.3 Perceived socio-ecological drivers and dimensions of water insecurity 158

5.1.4 Sociodemographic and community-level predictors of water insecurity 160
5.1.5 Microbiological and physicochemical quality of sources used by participants 161
5.2 THE LIVED EXPERIENCE OF WATER INSECURITY AND PATHWAYS TO HIV TREATMENT OUTCOMES 163
5.2.1 The lived experience of water insecurity among adults on ART 163
5.2.2 Pathways from water insecurity to HIV treatment outcomes 166
5.3 THE ASSOCIATION OF WATER INSECURITY WITH HIV TREATMENT OUTCOMES 171
5.4 LIMITATIONS 175

CHAPTER SIX: CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH 177

6.1 CONCLUSIONS 177
6.2 RECOMMENDATIONS 178
6.3 SUGGESTIONS FOR FUTURE RESEARCH 178

REFERENCES 181

APPENDICES 199

I. MAP OF STUDY AREA 199
II. INFORMED CONSENT FORM (ICF) 200
III. STUDY TOOLS 203
HOUSEHOLD QUESTIONNAIRE 203
HOUSEHOLD WATER INSECURITY EXPERIENCES SCALE (HWISE) 207
INDIVIDUAL WATER INSECURITY EXPERIENCES SCALE (IWISE) 208
HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS) 210
GENERALIZED ANXIETY TOOL 213
DEPRESSION TOOL 214
IDI GUIDE 215
FGD GUIDE 217
IV MASENO UNIVERSITY SCHOOL OF GRADUATE STUDIES (SGS) PROPOSAL APPROVAL 220
V MUSERC APPROVALS (ORIGINAL AND EXTENSION) 221
VI NACOSTI LICENSE 223
VII KISUMU COUNTY DEPARTMENT OF MEDICAL SERVICES, PUBLIC HEALTH & SANITATION APPROVAL 224
VIII: PHYSICOCHEMICAL PARAMETERS TESTED ON 34 WATER SAMPLES (N=23) WITH WHO ACCEPTABLE RANGES .225

LIST OF ABBREVIATIONS AND ACRONYMS

AIDS	Acquired immunodeficiency syndrome
AFD	The French Development Cooperation
AMREF	The African Medical and Research Foundation
ART	Antiretroviral Therapy
ARV	Antiretroviral
ASPIRES	Accelerating Strategies for Practical Innovation & Research in Economic Strengthening
CCC	Comprehensive Care Centers
CDC	The Centres for Disease Control and Prevention
CIHEB	Center for international health, education, and biosecurity
CIPD	County Integrated Development Plan
FAO	Food and Agriculture Organization
GIS	Geographic Information System
HIV	Human immunodeficiency virus
HTS	HIV Testing Services
ICC	Intra-cluster correlation
ICF	Informed Consent Form
IFAD	The International Fund for Agricultural Development
IFRC	International Federation of Red Cross and Red Crescent Societies
KEBS	Kenya Bureau of Standards
KIWASCO	Kisumu Water Services Company
KNBS	Kenya National Bureau of Statistics
LVSWSB	Lake Victoria South Water Services Board
MoH	Ministry of Health
NIH	National Institutes of Health
NSDCC	National Syndemic Diseases Control Council
PEPFAR	U.S. President's Emergency Plan for AIDS Relief
PWH	People with HIV
RNA	Ribonucleic acid
SDG	Sustainable Development Goal

SSA	Sub-Sahara Africa
UNAIDS	The Joint United Nations Programme on HIV/AIDS
UNICEF	United Nations Children's Fund (United Nations International Children's Fund)
WBG	World Bank Group
WEF	World Economic Forum
WFP	UN World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WWAP	United Nations World Water Assessment Programme
WWH	Women with HIV

OPERATIONAL DEFINITION OF TERMS

Water insecurity: In this thesis, water insecurity is conceptualized as a structural condition arising from challenges with availability (scarce or excess), access, and quality that disrupt HIV treatment continuity, daily life activities, and undermines overall well-being of individuals.

Structural: In this study, the term 'structural' covers the upstream systems and conditions, including environmental factors, water infrastructure, service delivery, governance, and socioeconomic inequalities that produce and reproduce water insecurity independently of individual efforts, to shape what people are able to do and be.

Determinants of water insecurity: Include socio-ecological drivers and dimensions of water insecurity.

Socio-ecological drivers of water insecurity: In this study, these referred to the social and environmental conditions such as poverty, population size, infrastructure, climate, and geographic factors that create conditions and manifestations/dimensions of water insecurity in the study area.

Dimensions of water insecurity: In this study, the dimensions of water insecurity were:

- Availability (scarcity and excess water).
- Access (affordability, distance, time, & reliability of obtaining water).
- Quality – water safety with regards to physical, chemical, and pathogenic contamination.

HIV treatment outcomes (composite case definition): At least one of the following outcomes in the 6 – 12 months prior to data collection, with viral load as the primary classifier:

- Sub-optimal viral suppression (≥200 copies/ml^3)
- AIDS-defining illnesses/opportunistic infections
- Missed clinic visits.
- Low CD4 count (<200 cells/mm^{3}while on effective treatment)

Lived experience: A qualitative account of the experiences, choices, and behaviors of people who experience a phenomenon and the knowledge they gain from their experiences and choices based on their society.

In this study, the lived experience of water insecurity was defined as individuals' subjective experience of excessive, intermittent or inadequate access to sufficient, safe, and culturally

acceptable water for household, health, and livelihood needs; covering chronic shortages, acute supply disruptions, excessive availability; and manifesting in physical illness and injuries, psychosocial stress, social friction, economic strain, and adaptive or maladaptive coping behaviors among adults on ART.

***People with HIV (PWH):** This thesis adopted the term 'people with HIV (PWH) consistent with current person-first and humanizing language practices in HIV research to refer to the broader population from which the study population (adults on ART) were drawn. The terms PWH and Women with HIV (WWH) were used with regards to existing literature. When specifically referencing the study population from whom data were collected, the term adults on ART was used.

LIST OF TABLES

Table 3.1: Age-stratified breakdown of FGD & IDI participants by gender.....77

Table 3.2: Water quality parameters, analytical methods, and WHO & KEBS guidelines.....97

Table 3.3: Clustering relationships into functional mechanism groups.....101

Table 3.4: Synthesized mechanisms with corresponding explanatory pathways.....102

Table 3.5: Summary of methods, data tools/sources and analyses by study objective..... ..105

Table 4.1: Participant socio-demographic characteristics of PWH by sex (N=433).....111

Table 4.2: Socio-demographic predictors of water insecurity.....117

Table 4.3: Community-level predictors of water insecurity 118

Table 4.4: Distribution of sampled water sources by source type.....119

Table 4.5: Microbiological classification of water samples from sources (n = 34).....120

Table 4.6: Descriptive analysis of microbiological contamination by source category.....121

Table 4.7: Physicochemical characteristics of water sources & guideline exceedances 123

Table 4.8: Selected physicochemical parameters compared with guideline limits 124

Table 4.9: Pathways linking water insecurity to HIV treatment outcomes among PWH 145

Table 4.10: Unadjusted and Adjusted association of water insecurity and selected covariates with HIV treatment outcomes among PLWV (N=356).....150

Table 4.11: Associations between water insecurity severity and HIV Treatment Outcomes.....152

Table 4.12: Adjusted estimates of sex as a modifier of association between water insecurity and HIV treatment outcomes (N=356).....152

Table 4.13: Adjusted predicted probabilities of poor HIV treatment outcomes by water insecurity and sex (N=356).....153

Table 4.14: Unadjusted associations for intermediate variables linking water insecurity to HIV treatment outcomes (N= 356)..... 155

LIST OF FIGURES

Figure 1.1: Kisumu County HIV estimates.....6

Figure 2.1: The Socio- Ecological Model.....19

Figure 2.2: Conceptual framework.....62

Figure 3.1: Study design.....68

Figure 3.2: Flowchart of Phase III – case-control study.....71

Figure 3.3: Directed Acyclic Graph (DAG).....90

Figure 3.4: Framework analysis flowchart..... 100

Figure 4.1a: Household water insecurity scores by category……..... 112

Figure 4.1b: Kernel density plot…….....112

Figure 4.2: Perceived Socio-ecologic drivers of water insecurity.....113

Figure 4.3: Perceived dimensions of water insecurity.....115

Figure 4.4: Microbiological contamination of sampled water sources by source category.....121

Figure 4.5a: Microbiological and physicochemical safety classification of sampled sources.....124

Figure 4.5b: Overlap between Microbiologically and physicochemically safe sources (n=34).....125

Figure 4.6: Predicted probabilities of HIV treatment outcomes by water insecurity status and sex among PWH with 95% confidence intervals.....154

Figure 4.7: A novel conceptual model of pathways to HIV treatment outcomes.....156

CHAPTER ONE: INTRODUCTION

This chapter provides a conceptual and structural framework for investigating the relationship between water insecurity and HIV treatment outcomes. It begins by giving a synopsis of the HIV epidemic and the evolution of unsuccessful treatment outcomes despite availability of effective treatment, hypothesizing water insecurity as a structural determinant influencing those outcomes among adult people receiving antiretroviral therapy. In the background, a theoretical framework anchoring the study is provided, as well as a synthesis of relevant literature, while identifying critical gaps warranting a scientific investigation. Following this background, the chapter outlines the statement of the problem, research objectives, corresponding research questions and hypotheses, the significance of the study, and its underlying assumptions.

1.1 Background to the Study

Four decades after it first emerged in the early 1980s, HIV remains a major global problem of public health importance. Antiretroviral therapy (ART) has brought transformation in the prognosis of people with HIV (PWH); however, optimal HIV treatment outcomes depend on consistent adherence to ART and sustained engagement in care (UNAIDS, 2022a). Despite the global efforts to achieve universal access to ART, treatment outcomes remain suboptimal for many PWH, particularly in sub-Saharan Africa (SSA) (Magura et al., 2025), with ongoing new infections every year (UNAIDS, 2025; WHO, 2025b). The Sustainable Development Goals (SDGs) prioritize good health and well-being in SDG 3, with target 3.3 specifically targeting the eradication of the AIDS epidemic by the year 2030. It is estimated that in 2023, just 7 years short of the target, almost 40 million people were living with HIV worldwide, with about 75% of them in the WHO African Region (WHO, 2025a). In the previous year, there was an increase in new infections, partly attributed to a reduced public health response to HIV; and despite the gains made with ART, global HIV targets remain unmet (UNAIDS, 2022a): The UN 90-90-90 targets fell short, and the consecutive 95-95-95 seem unlikely to be met by 2030, raising substantial questions: why, given the worldwide availability of effective HIV treatment? What non-biomedical factors might be responsible for the persistent inequities in HIV prevalence, incidence, and treatment outcomes, despite the expanded HIV comprehensive care service delivery?

The persistence of these gaps indicates that HIV treatment outcomes are not only determined by the behavior of individuals or access to clinical services but could be shaped by broader structural

conditions that influence day-day living life activities. Accordingly, to achieve equitable HIV outcomes, there is need to go beyond biomedical approaches towards addressing social and material environments in which PWH manage their health (Julaihi, 2026). There is a growing recognition that HIV outcomes are also determined by structural factors, and several factors are cited as undermining successful HIV treatment outcomes for PWH who are on treatment with ART. One of these emerging factors is water insecurity (Boateng et al., 2022; Miller et al., 2021a; Nagata et al., 2021). According to these authors, water is essential for health and well-being, however, reliable access to safe and sufficient water is not guaranteed to all. Previous studies have provided evidence for syndemic relationships between resource insecurities and HIV and shown how such mutually reinforcing conditions may be important in the HIV response. For example, HIV and food insecurity have been shown to interfere with treatment effectiveness among PWH, thus increasing their odds of sub-optimal viral suppression (Aibibula et al., 2017; Cohen et al., 2022). Food insecurity is known to not only co-occur with but is also partly driven by water insecurity (Bethancourt et al., 2023; Boateng et al., 2022; Miller et al., 2021a). Access to water, in consonance with SDG 6, is a critical structural determinant of HIV outcomes (Nagata et al., 2021). However, compared to food insecurity, the role of water insecurity and the mechanisms that link it to HIV treatment outcomes among PWH have not received much empirical attention. This is a gap that persists despite the SDG 6 commitments to ensure universal access to clean water and sanitation with the requirement to meet, by the year 2030, targets 6.1 on safe and affordable drinking water and 6.3 on improved water quality.

Water insecurity refers to a state in which people experience a diminished capability of attaining reliable, affordable, adequate, or safe water; such that their physical and mental well-being; and their ability to engage productively in social and cultural activities is compromised (Jepson et al., 2017). It is an important yet overlooked driver of poor HIV treatment outcomes among PWH in low-income countries (Miller et al., 2021a; Nagata et al., 2021). Water insecurity has a deleterious effect on people's health and well-being and contributes to a significant increase in the burden of disease worldwide (Achore et al., 2020; Rosinger & Young, 2020). Water is essential for hydration, medication intake, hygiene, food preparation, and the prevention of opportunistic infections (Nagata et al., 2021; Nutor et al., 2024), functions that are central to effective HIV treatment and care. It directly affects hygiene and sanitation, nutrition, physical health and psychosocial well-being (Boateng et al., 2022; Miller et al., 2021a; Wutich, 2020) and may present

considerable barriers to ART adherence, ultimately leading to worse HIV outcomes, including higher viral loads and greater risk of opportunistic infections (Nagata et al., 2021). Water insecurity also impacts on overall social development by affecting educational attainment, livelihood activities and gender equality (Ahmed et al., 2021). Additionally, studies have shown that water insecurity is an even greater challenge among populations with chronic illnesses such as PWH on ART (Boateng et al., 2022). In contexts where water is unreliable, unsafe, or unaffordable, these basic living requirements may be compromised, resulting in ART adherence challenges, increased vulnerability to illness, and exacerbation of physical and psychosocial stress (Miller et al., 2021b). However, there is a dearth of data on studies that have been done on water insecurity as an existential threat with regards to how water scarcity, excess availability, unreliable access, and poor quality may be associated with the burden of disease among PWH, and how they may be affecting HIV management efforts in resource-poor regions.

Historically, health problems associated with water initially appeared in records after the epidemiological work of Dr John Snow in 1854, demonstrating the link between unsafe water and a disease outcome. Over time, terminology like water scarcity, water stress and water risk, each representing a different dimension like volumetric shortage, demand pressure, and water as a hazard respectively, were used to describe challenges arising from water and water resources. Thus, water scarcity informed water stress, and both contributed to perception of water risk (Pacific Institute, 2014). The application of the concept of water insecurity in scientific discourse relating water and human health is recent; having been used for just about two decades (Wutich, 2020).

Global estimates indicate that annually, about four billion people experience severe water scarcity at least once a month (Mekonnen & Hoekstra, 2016; Stoler et al., 2020). About half a billion people in the Asia and Pacific region do not have access to adequate water (ADB, 2022). In India, with only 4% of the world's fresh water supplies, 163 million people lack access to safe drinking water. In Latin America and the Caribbean, about 150 million people experience water scarcity (World Bank blogs, 2022), while in the Middle East and North Africa (MENA) region, the World Bank Group reports that life and livelihoods are threatened by unprecedented water scarcity (WBG, 2023). These patterns show that water insecurity is not confined to arid regions only, but is a multidimensional global challenge affecting diverse ecological and socio-economic settings. Water insecurity is part of the water crisis and a key contributor to the global burden of disease

(Adams et al., 2022). According to the World Bank (2021), water insecurity hampers progress, inhibits development, and undermines human well-being. It results in global economic setbacks across multiple fronts, such as property destruction caused by floods and food losses due to droughts and water scarcity. According to the World Bank's Water Security Diagnostic Initiative (WSDI), while the degradation of ecosystems and damage from pollution are challenging to quantify, they pose a substantial threat to future water availability, particularly in the context of climate change (World Bank, 2021). Not only does water insecurity present an existential threat to humanity across the globe, but also a clear and present danger especially to under-resourced populations, a threat that is even higher within the Global South where nearly a third are water insecure (Matchawe et al., 2022; WHO & UNICEF, 2021).

In Sub-Saharan Africa (SSA), more than 400 million people lack access to clean drinking water. Water insecurity thus poses one of the most significant public health issues in the region (Mason et al., 2019). It is projected that in the future, global problems of water availability, which include water scarcity and excess (flooding), will affect populations more severely. Similarly, it is anticipated that there will be greater challenges with water access, quality and acceptability (Mekonnen & Hoekstra, 2016; Rosinger & Young, 2020; Wutich, 2020). These challenges are generally attributed to a changing climate, changing socio-economic and ecologic dynamics, lack of equity in resource distribution, and regional conflicts (Greve et al., 2018; UNICEF, 2022). With millions of people suffering from starvation and having little access to water, water insecurity and food insecurity remain vital topics critical to attaining global health goals (Koyratty et al., 2021).

Socio-economic determinants of water insecurity include rapid population growth, especially in developing countries (Mulwa et al., 2021), widespread poverty (OASENSE, 2022), and unsustainable coping mechanisms among the affected (Achore et al., 2020). From the ecological perspective, water insecurity is driven by topographical factors, especially the hydrologic and geologic conditions of an area (Tamesgen et al., 2023). These geospatial characteristics are linked to water supply availability, infrastructure development, and governance practices (Veettil et al., 2022), water extraction (Greve et al., 2018), and water contamination (Olisah et al., 2021). Additionally, water insecurity is driven by climate change-related extreme weather events (EWEs) including floods, droughts, tropical cyclones, heatwaves, and severe storms (WHO, 2023a). The dimensions of water insecurity include water availability (scarcity and excess), water access (affordability and reliability), and water quality which focuses on water safety with regards to

pathogenic and chemical contamination (Achore et al., 2020; Guppy et al., 2017; Koyratty et al., 2021; Rosinger & Young, 2020). However, there remains significant knowledge gaps at the intersection of socio-ecological drivers and dimensions of water insecurity and HIV care among PWH. Further, the documentation of the mechanisms linking water insecurity to HIV treatment outcomes rarely includes the lived experiences and pathways through which water insecurity may impede successful HIV treatment outcomes.

With an HIV prevalence of about 3.7% (WHO, 2023c), Kenya is among the 15 countries globally and in SSA with the highest HIV prevalence (WHO, 2025a). The country is also classified as water-stressed with total renewable water availability per capita of about 570m^3 per annum (Knoema, 2020). About 47% of Kenyans aged 15 years and above are water insecure (Young, 2021). While Kenya has a generalized HIV epidemic and the regional HIV prevalence is well documented, disaggregated regional water insecurity data is still scant. Northern and Coastal arid and semi-arid lands (ASALs) are known to experience perennial severe water scarcity principally due to prolonged drought (UNICEF, 2022). Counties around Lake Victoria like Kisumu, Homa Bay and Siaya experience seasonal flooding and drought. These latter are also the regions with the highest burden of HIV in Kenya, with women having a greater burden at 14.9% compared to men at 8.6% in Kisumu County (NSDCC, 2024). While some preliminary research has identified an association between water insecurity and adverse HIV outcomes in western Kenya (Nagata et al., 2021), evidence remains insufficient on whether water insecurity is independently associated with HIV treatment outcomes, and whether this association is modified by sex among PWH.

According to the National Syndemic Diseases Control Council (NSDCC), Kisumu County has the highest prevalence of HIV (11.7%) in Kenya, about three times the national average; a 14% treatment gap, and a 17% viral suppression gap out of the 135,550 PWH in the County (NSDCC, 2024). Data from the 2022 World AIDS Day Report show that it is one of the Counties leading in new HIV infections and AIDS-related deaths in Kenya (UNAIDS, 2022b).

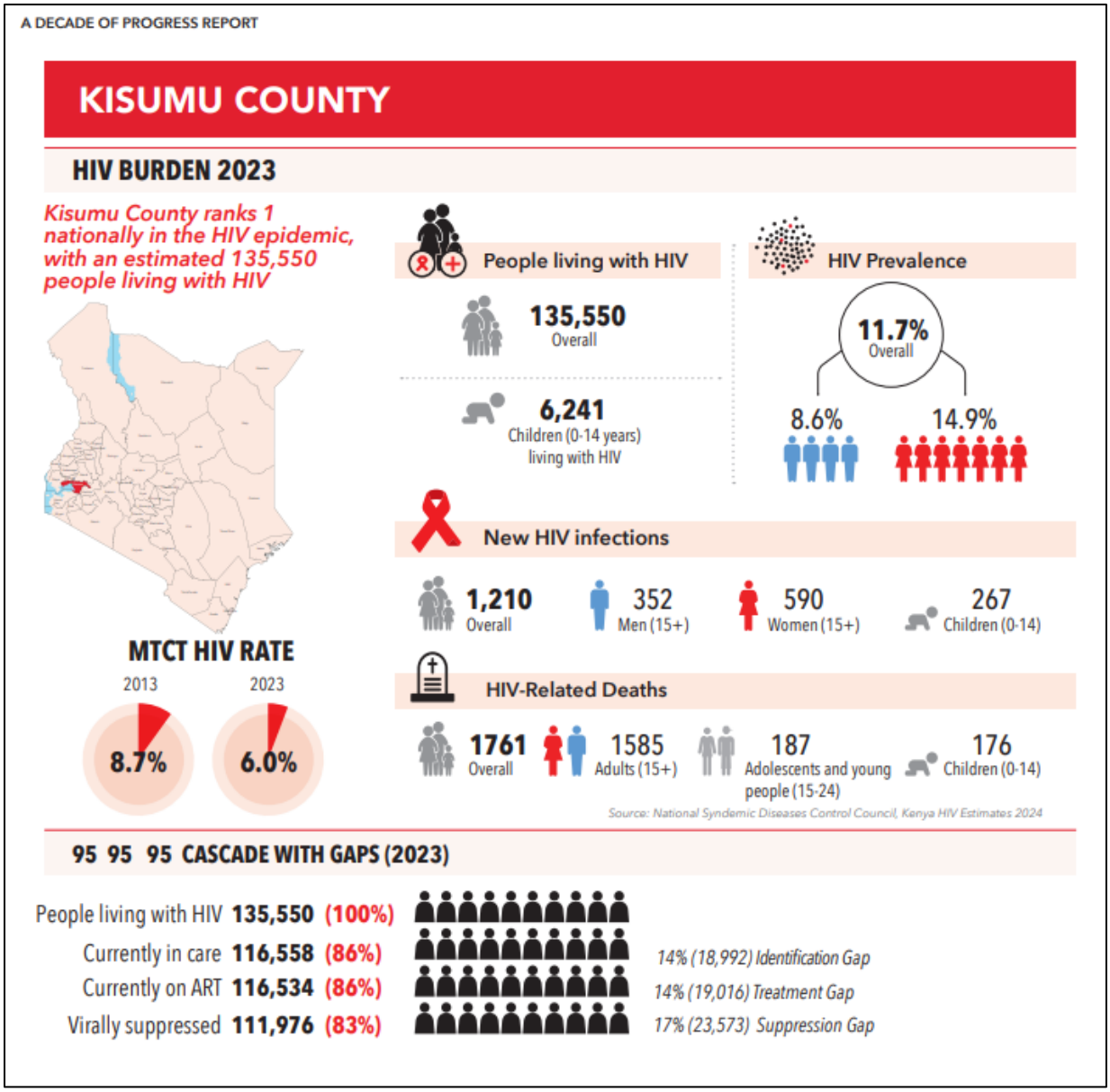


Figure 1: Kisumu County HIV estimates (NSDCC, 2024)

While Kisumu County is located near Lake Victoria, water availability, access and quality may not be uniform across the region. Factors such as population density, infrastructure, water management practices, and socio-economic disparities could lead to variations in water insecurity. The County experiences seasonal dry conditions in some parts and flooding in others. Overall, only 42% of the population has access to water from improved sources (Okwara et al., 2024). Access to piped water remains low and is largely concentrated in urban areas, with only 8.3% of households connected within individual dwellings and an additional 10.9% relying on shared

connections within plots or yards, according to the 2019 census (KNBS, 2019). However, among PWH in Kisumu County, there is no documented evidence on the prevalence of water insecurity. The largest water source for many people is Lake Victoria, which has been reported to have high levels of pollution (Kundu et al., 2017; Nalumenya et al., 2024; Opere et al., 2022; Outa et al., 2020), even evidenced by the proliferation of harmful algal blooms (Roegner et al., 2020).

The Kisumu County HIV and AIDS Strategic Plan (2014/2025-2018/2019) identified the fishing industry along Lake Victoria's 567 km² of water coverage as a primary socio-economic driver of new infections, alongside informal settlements and clinical hurdles like low baseline viral suppression, but it left the intersection of water access and physical treatment adherence unaddressed. Consequently, a critical intervention gap still exists because the plan had no explicit water, sanitation, or hygiene (WASH) protocols across its strategic directions. The document acknowledged this lack of intersectoral integration, citing "improper co-ordination between health and other sectors" as a key structural weakness. Furthermore, it provided no policy mandate or resource allocation to train community health volunteers in managing household water insecurity. Later, the Kisumu County Integrated Development Plan (CIDP) identified water pollution and low household water coverage among the County's priority development concerns (CGK, 2023). What remains unknown is the prevalence and manifestation of water insecurity among adults on ART in Kisumu, and there is a gap in our knowledge of the exact determinants: the drivers and dimensions that may predispose the adults on ART around the world's second largest fresh-water lake to challenges with water availability, access, and quality. In addition, while emerging evidence has largely relied on cross-sectional analyses, the magnitude of association between water insecurity and HIV treatment outcomes in this high-burden setting remains insufficiently examined using rigorous study designs that allow for more analytically robust estimation of measures of association.

Theoretically, this study first draws from the Socio-Ecological Model (SEM), originally developed by Urie Bronfenbrenner in 1979, which can explain studies on resource insecurities and their impact on health outcomes. The theory highlights the complex interplay between individual, relationship, community, societal and environmental factors that impact health and well-being. Secondly, it also guided by the Capability Approach (CA), founded by Amatya Sen in 1999 and later developed by Martha Nussbaum in 2011; to provide an interpretive lens for understanding how water insecurity constrains the real lived freedoms and day-to-day functionings of PWH.

While the SEM structures the analysis of determinants and associations across levels, the CA deepens understanding of lived experience of water insecurity.

Access to reliable and potable water is important for PWH. Their survival is contingent upon access and adherence to ART, because taking ART as required is mandatory for the attainment and maintenance of viral suppression, and PWH with no current sexually transmitted infection (STI) who have maintained undetectable viral load for a period of 6 months do not transmit HIV (Eisinger et al., 2019). However, factors that lead to treatment interruptions and non-adherence can cause incomplete HIV RNA suppression and faster progression to AIDS. Viral rebound tends to take place within 2 - 3 weeks of ART stoppage due to HIV persistence in CD4 cells with latent infection (Eisinger et al., 2019; Pannus et al., 2020). Since areas with the highest HIV prevalence also tend to be resource limited, it is likely that PWH in these areas do not have access to reliable potable water. Water-related treatment interruptions may lead to viral rebound, opportunistic infections, or treatment failure. These clinical realities show the importance of identifying structural barriers that might disrupt ART adherence, especially in resource-limited settings.

In this era of worldwide HIV treatment availability, maintaining the momentum towards HIV eradication is dependent on the identification and surmounting of all the important barriers to ART adherence that may lead to sub-optimal viral suppression and treatment failure. Research on water insecurity among PWH in Kisumu County is scant, and there is need to conduct comprehensive and formative studies that can help with the identification of determinants, pathways and potential interactions that may affect HIV treatment outcomes. Additionally, it is necessary to quantify the association of water insecurity and HIV treatment outcomes. Despite existing biomedical efforts to address HIV treatment outcomes, the complex and multifaceted relationship between water insecurity and HIV remains underexplored.

This study aimed to generate reliable preliminary evidence that would later guide the design, implementation, and scaling of appropriate sustainable interventions addressing water insecurity for PWH on ART in general, and specifically for adults on ART in Kisumu County and beyond. As its fundamental focus, this study sought to answer the guiding question: What are the determinants, mechanisms, and association of water insecurity with HIV treatment outcomes among adults on ART in Kisumu County?

1.2 Statement of the problem

HIV interventions are built on the universal assumption that providing antiretroviral therapy (ART) alone is sufficient to achieve HIV treatment success, but resource constraints can undermine adherence. Kisumu County has one of the highest HIV prevalence rates in Kenya at 11.7% alongside a 17% gap in viral suppression (NSDCC, 2024). At the same time, it faces persistent water-related challenges, including localized dry spells, seasonal flooding, inequitable piped water coverage, and questionable water quality. Within this context, many households experience water insecurity, with only 42% of the population having access to improved water sources (Okwara et al., 2024). In a setting where close to 140,000 PWH depend on uninterrupted ART for survival, water insecurity may have direct and immediate implications for treatment continuity. However, evidence on its prevalence is speculative, and the socio-ecological drivers and dimensions of water insecurity among adults on ART in Kisumu County remain insufficiently characterized, limiting the empirical foundation for explaining it and hindering our understanding of its impacts on HIV health**.**

Water insecurity extends beyond resource deprivation, impacting overall social determinants of health like education, settlement, livelihoods, and healthcare access. However, context-specific evidence on the biological and psychosocial pathways by which it may contribute to poor HIV treatment outcomes among PWH in Kisumu County is limited. To date, the lived experiences of water insecurity among adults on ART and mechanisms through which they may hinder successful HIV treatment outcomes are poorly understood. Without an in-depth exploration, the ways in which water insecurity constrains daily treatment practices and health-seeking behaviors among PWH cannot be fully explained or effectively mitigated.

It is known that HIV treatment interruptions compromise viral suppression, increase the risk of vertical and horizontal HIV transmission, and lead to faster progression to AIDS. These consequences are serious for a high prevalence setting like Kisumu County, where even short-term disruptions in ART may have significant individual and public health consequences. It is also known that women in resource-limited settings bear a disproportionate burden of both water insecurity and HIV, reflecting underlying gendered inequalities. Despite this base understanding, rigorous evidence quantifying the association of water insecurity with HIV treatment outcomes among adults on ART in Kisumu County is limited, and it is not clear whether the association is modified by sex. This study sought to bridge these knowledge gaps by investigating the

determinants, mechanisms, and association of water insecurity with HIV treatment outcomes among adults on ART in Kisumu County. Its goal was to generate preliminary insights and critical evidence in this under-researched area by addressing the questions that linger with regards to treatment interruptions and potential viral rebound among water insecure adults on ART in Kisumu County.

1.3 Research Objectives

1.3.1 General objective

To investigate the determinants, the mechanisms, and the association of water insecurity with HIV treatment outcomes among adults on ART in Kisumu County.

1.3.2 Specific objectives

1. To estimate the prevalence and characterize the socio-ecological drivers and dimensions of water insecurity among adults on ART in Kisumu County.
2. To explore the lived experiences of water insecurity and pathways through which it may impede successful HIV treatment outcomes among adults on ART in Kisumu County.
3. To determine the association between water insecurity and HIV treatment outcomes among adults on ART in Kisumu County, and assess whether sex modifies this association.

1.4 Research Questions

1. What is the prevalence and the underlying socio-ecologic drivers and dimensions of water insecurity among adults on ART in Kisumu County?

2. What are the lived experiences of water insecurity and through what pathways does it impede successful HIV treatment outcomes among adults on ART in Kisumu County?

1.5 Hypotheses

1 a) H_0: There is no association between water insecurity and HIV treatment outcomes among adults on ART in Kisumu County.

b) H_0: Sex does not modify the association between water insecurity and HIV treatment outcomes among adults on ART in Kisumu County.

1.6 Significance of the Study

Without a clear understanding of the prevalence, drivers and dimensions of water insecurity in this high HIV burden setting, efforts to address it as a structural vulnerability among PWH in general lack an empirical foundation. This study extends public health knowledge by generating context-specific insights into the prevalence, determinants, lived experiences, and consequences of water insecurity on HIV treatment outcomes among adults on ART in Kisumu County. It contributes to efforts to reduce the burden of water insecurity among adults on ART by identifying the specific determinants that affect their access to safe, reliable, and adequate water. The study will be useful for developing and implementing targeted interventions that may: 1) mitigate the risk posed by water insecurity to adults on ART, and 2), improve their health and well-being. Understanding the facilitators of water insecurity will inform the design of community and household level interventions that are socially responsive and geographically appropriate, ultimately improving reliable water access and reducing the psychosocial and health toll of water insecurity for this vulnerable population. The study contributes to knowledge by developing a novel conceptual model for understanding modifiable pathways linking water insecurity to treatment outcomes. Additionally, this research may be useful for developing and implementing scalable and sustainable evidence-based solutions to water insecurity to mitigate its impact on HIV treatment outcomes within the study population and beyond.

Despite the availability and access to effective HIV treatment, there are adults on ART who still progress to AIDS and death despite being on ART. Because of non-adherence to treatment, PWH can experience treatment failure and viral rebound, creating an avenue through which the burden of HIV will continue to rise due to new vertical and horizontal infections, potentially increasing the prevalence of HIV. This study could improve HIV care and clinical management by elucidating the behavioral and structural pathways through which water insecurity disrupts HIV treatment adherence, retention, and viral suppression. Findings from this study could thus deepen clinical understanding of non-biomedical barriers to ART effectiveness and highlight how water-related challenges intersect with nutrition, hygiene, and mental health to undermine HIV care. By quantifying the association between water insecurity and HIV treatment outcomes and exploring

the pathways through which this relationship may occur, the study advances science by generating robust evidence of association through a more rigorous analytical study design to inform development and testing of optimized strategies for sustaining HIV care continuity. Further, such quantification could equip clinicians, counselors, and community health workers with actionable insights to screen for and address water insecurity as part of comprehensive HIV care. This could contribute to the strengthening of the care continuum and reduction of preventable morbidity and mortality.

Systemic failures in water management, infrastructure, and governance continue to undermine equitable access to safe and reliable water in many parts of Kenya, including high HIV-burden regions like Kisumu County. At the policy level, this study will provide empirical evidence that may help to support the integration of water security considerations into HIV response strategies and broader health and development planning. Research on water insecurity among adults on ART in the study area may be useful for advancing learning and knowledge on how it may undermine progress towards the eradication of HIV; but may also be useful in promoting technical and better policy design for improving institutional infrastructure, water governance and local adaptive capacities. Findings from this study will help inform multisectoral responses that align with Kenya's commitments to SDG 3 (health), SDG 6 (water), and the national HIV strategic framework to improve treatment continuity, reduce viral rebound, improve and increase quality adjusted life years (QALYs) for adults on ART. By centering the voices and experiences of adults on ART in Kisumu County, the study will also elevate the policy relevance of water insecurity and advocate for investment in infrastructure, service delivery, and social protection programs that are tailored to the needs of populations most at risk.

1.7 Study Assumptions

This study assumed that:

i. Adults on ART in the study area experience some dimensions of water insecurity, despite them living near the second largest freshwater lake in the world.
ii. That water insecurity may be associated with poor HIV treatment outcomes, and the association may be modified by sex.

iii. That water insecurity is independently associated with HIV treatment outcomes after adjusting for other socio-demographic and clinical correlates and can therefore be measured as an independent construct.

iv. This study used a composite outcome, which is a combination of several possible singular outcomes, as the dependent variable. The underlying assumption surrounding the validity of the composite outcome (HIV treatment outcomes) was that the independent variable, which was water insecurity, has a similar influence across outcome components: missed clinic visits, sub-optimal viral suppression, low CD4 cell count, and AIDS-defining illnesses, which are of comparable importance in HIV management.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews and synthesizes the body of literature informing the examination of water insecurity as a structural determinant of HIV treatment outcomes. It includes literature that was subsequently included or contributed to peer-reviewed publications (Odak, Murnane, et al., 2026; Odak, Young, et al., 2026). While the synthesis presented here represents the original conceptual framing of the study, some text may show similarity to later published work derived from this thesis. All such publications are appropriately cited where relevant.

The chapter begins with overviews of the HIV epidemic and water insecurity burdens and their conceptual framing, establishing the broader public health context. It is important to point out here that this literature review draws on evidence from studies on people with HIV (PWH) in general, though this study focused on adults on ART in particular. The chapter also introduces the Socio-Ecological Model which provides a theoretical foundation guiding the quantitative objectives of the study, followed by broad literature and critical synthesis of scholarship per specific objective. Additionally, the section introduces the Capability Approach to anchor the qualitative study in specific objective two. Drawing on these insights, the chapter identifies major empirical and methodological gaps, gives a summary of concepts, and culminates in the study's conceptual framework.

2.1 Socio-ecological determinants (drivers and dimensions) of water insecurity

Water insecurity does not arise randomly; it is produced through layered socio-ecological processes operating across structural, community, and household levels. Guided by the socio-ecological model, this section synthesizes existing literature on the burden of water insecurity and the determinants of water insecurity, distinguishing between the underlying socio-ecological drivers that generate vulnerability and the dimensions through which water insecurity manifests at the community and household levels. Understanding both components is critical for situating water insecurity as a structurally produced phenomenon.

2.1.1 Water insecurity: overview of burden and conceptual framing

Globally, the water crisis is increasing in magnitude and severity, with deleterious consequences for people in affected areas in terms of water being scarce, excessive, unreliable, inaccessible, or contaminated (WEF, 2020). Water insecurity represents a core human dimension of this crisis and

is a key contributor to the global burden of disease (Young, Collins, et al., 2019). More than 4 billion people on the planet experience water stress at least once every month and half a billion of them experience severe water scarcity throughout the year (Mekonnen & Hoekstra, 2016). This statistic is even higher within the Global South where nearly a third of the population is water insecure (WHO, 2022a). With more than 400 million lacking access to clean drinking water in Sub Saharan Africa, water insecurity poses one of the most significant public health threats in the region. It is projected that in the near future, global problems of water availability, which include water scarcity and flooding, will affect populations more severely. Similarly, it is anticipated that there will be greater challenges with water access, quality and acceptability (Mekonnen & Hoekstra, 2016; Rosinger & Young, 2020; Wutich, 2020). These challenges are generally attributed to a changing climate, changing socio-economic and ecologic dynamics, lack of equity in resource distribution, and regional conflicts (Greve et al., 2018; UNICEF, 2022). A recent report by the African Development Bank shows that 32.3% (387 million) of the SSA population lacked basic drinking water services as of the year 2020, representing most of the global population without safe water access (African Development Bank, 2025). This water insecurity burden overlaps geographically with the highest global prevalence of HIV (UNAIDS, 2023b). Despite the burgeoning research interest in the role of water insecurity in health, its role among PWH has received little attention. Importantly, water insecurity rarely exists in isolation; it frequently co-occurs with food insecurity and poverty, reinforcing cycles of deprivation that undermine population health (Koyratty et al., 2021).

Kenya is classified as a water-stressed country with total renewable water availability per capita of about 570m^3 per annum (Knoema, 2020). This level falls substantially below the 1,000 m^3 threshold for water scarcity, situating Kenya within conditions of chronic structural water deficit and underscoring the macro-level constraints shaping water insecurity. About 47% of Kenyans aged 15 years and above are water insecure (S. L. Young, 2021), indicating that water insecurity is not only environmentally determined but also socially and economically distributed across populations. Nationally, disaggregated regional water insecurity data is still scant; reflecting a broader gap in capturing the spatial heterogeneity of water insecurity experiences and constraining context-specific policy responses. Northern and Coastal arid and semi-arid lands (ASALs) are known to experience perennial severe water scarcity principally due to prolonged drought (UNICEF, 2022), illustrating the role of hydrological variability and climate extremes in shaping

water availability. However, water insecurity is not confined to the ASALs. Counties around Lake Victoria like Kisumu, Homa Bay, Migori, and Siaya experience seasonal flooding and drought, highlighting the coexistence of water excess and scarcity as dual manifestations of hydrological stress. This pattern demonstrates that water insecurity is multi-dimensional, encompassing not only insufficient supply but also variability, unreliability, and exposure to extreme events that disrupt access and utilization.

Within Kisumu County, water insecurity reflects the intersection of environmental exposure and socio-ecological determinants. Despite its proximity to Lake Victoria, water availability, access, and quality are unevenly distributed, demonstrating that physical proximity to water sources does not necessarily translate into water security. Instead, population density, infrastructure limitations, water governance, and socio-economic inequalities shape differential access to safe and reliable water. The County experiences seasonal dry spells in some areas and flooding in others, reflecting increasing climate variability and reinforcing the instability dimension of water insecurity.

Access indicators further reveal structural deficiencies in water infrastructure and service delivery. Only 42% of the population in Kisumu County has access to water from improved sources (Okwara et al., 2024), while piped water access remains limited and concentrated in urban areas, with just 8.3% of households having in-dwelling connections and 10.9% relying on shared sources (KNBS, 2019). These patterns point to significant constraints in the access dimension of water insecurity, particularly in terms of affordability, reliability, and distance to water sources. Consequently, many households depend on alternative sources, including surface water, which may be unsafe.

Water quality constitutes an additional and critical dimension of water insecurity in Kisumu County. Lake Victoria, the primary water source for many residents, has been reported to have high levels of pollution (Kundu et al., 2017; Nalumenya et al., 2024; Opere et al., 2022; Outa et al., 2020), reflecting contamination from urban runoff, wastewater discharge, and agricultural activities. The proliferation of harmful algal blooms (Roegner et al., 2020) further compromises water safety, illustrating how environmental degradation interacts with water quality to exacerbate water insecurity. In recognition of these challenges, the Kisumu County Integrated Development Plan identifies water pollution and low household water coverage as priority concerns (CGK, 2023), underscoring the persistence of systemic gaps in water governance and infrastructure.

From the foregoing literature, the Kenyan and Kisumu County contexts illustrate that water insecurity is not solely a function of water scarcity but arises from the dynamic interaction of multiple constraints, shaped by climatic variability, infrastructural limitations, and socio-economic inequalities. This reinforces the need to conceptualize water insecurity as a multi-dimensional and context-specific phenomenon, particularly in settings characterized by both environmental vulnerability and uneven development.

According to the World Bank (2021), water insecurity hampers progress, inhibits development, and undermines human well-being. It results in global economic setbacks across multiple fronts, such as property destruction caused by floods and crop losses due to droughts and water scarcity. Beyond immediate economic losses, ecosystem degradation and pollution threaten long-term water sustainability, suggesting that water insecurity is not only a present crisis but a structural and intergenerational challenge (World Bank, 2021).

The concept of water insecurity as applied in scientific parlance involving water and human health is relatively recent; having been used for just about two decades (Cook & Bakker, 2012; Wutich, 2020). Water insecurity frequently exists in regions with high HIV incidence, raising the possibility that the two epidemics are converging or syndemic, similar to how HIV and food insecurity co-occur (Krumdieck et al., 2016; Workman & Ureksoy, 2017). In areas of high prevalence of HIV and AIDS, the inability to attain reliable, affordable, adequate, and safe water presents additional challenges to the health and well-being of PWH. Prior research shows that in resource-poor settings, PWH who have water insecurity have higher odds of poor HIV outcomes; with viral loads of more than 1000 copies/mL as well as AIDS-defining illnesses (Nagata et al., 2021). The literature suggests reasons for the association but does not explain the mechanisms responsible for the association. According to Workman (2017), water insecurity is a health-threatening social stressor whose effect has not been adequately theorized or empirically examined in relation to the HIV epidemic.

Water insecurity refers to a state in which people experience a diminished capability of attaining reliable, affordable, adequate, or safe water; such that their physical and mental well-being; and their ability to productively engage in social and cultural activities is compromised (Jepson et al., 2017). According to the World Bank (2020), access to water supply and inadequate sanitation facilities represents only one aspect of water insecurity. Additional dimensions of water insecurity

include excess water, insufficient water, and water contamination that render it unsuitable for use. Collectively, these various dimensions of water insecurity can lead to significant disruptions and exacerbate vulnerabilities in social, economic, and environmental systems (Schoch & Lakner, 2020).

Wutich (2019), defines water insecurity as a condition in which adequate and safe water for a productive and healthy life is deficient. Water insecurity manifests in various key dimensions. These include water availability (scarcity and excessiveness), water access (affordability and reliability), and water quality (safety with regards to pathogenic and chemical contamination) as the main problems that not only have a deleterious effect on people's health and well-being, but also significantly increase the burden of disease worldwide (Rosinger & Young, 2020; Workman & Ureksoy, 2017; S. L. Young, Boateng, et al., 2019). Rosinger & Young (2020) further distinguish manifestations of water insecurity as contamination denoting water quality, as well as overabundance and scarcity which are metrics for water availability. Amount of usage is another dimension highlighted by Workman et al., (2017), as an important dimension of water insecurity. Achore et al., (2020) also talk about adequacy as a dimension of water insecurity. According to Guppy & Anderson (2017), the available water is not always potable, reliable, accessible, or affordable for many people (Guppy et al., 2017). Koyratty et al., (2021) define water security as access to reliable and safe water in sufficient quantities and of acceptable quality for consumption, cleanliness, and economic output. According to Adams et al., (2020), water insecurity refers to the inability to access quality, affordable water in socially acceptable ways (Adams et al., 2020). Although terminology varies slightly across studies, emphasizing adequacy, usage, acceptability, or social access, there is broad consensus that water insecurity is multidimensional and extends beyond access to water infrastructure. Addressing water insecurity is crucial to improving health, well-being, and human capability, given its far-reaching effects on physical, mental, social, and economic outcomes. This study sought to provide an understanding on how the underlying drivers operate and interact across levels of influence by drawing on the Socio-Ecological Model (SEM) as an organizing framework.

2.1.2 The Socio-ecological Model

Water insecurity has both distal and proximal determinants. To conceptualize how these determinants shape water insecurity among adults on ART in Kisumu County, this study used the

Socio-ecological model (SEM), a framework which shows that individuals' health and well-being are influenced by several interconnected social and environmental factors. Guided by the SEM, this study conceptualized water insecurity as influenced by individual, household, community, and structural factors. In that regard, the relationship between water insecurity and HIV treatment outcomes cannot be fully explained without taking into account the upstream socio-ecologic factors that create conditions of water insecurity, the more proximal and contextual factors that cause manifestation of water insecurity at the communal and household levels, and downstream factors that influence experiences, choices, and the HIV health-seeking behaviors of PWH at the individual level.

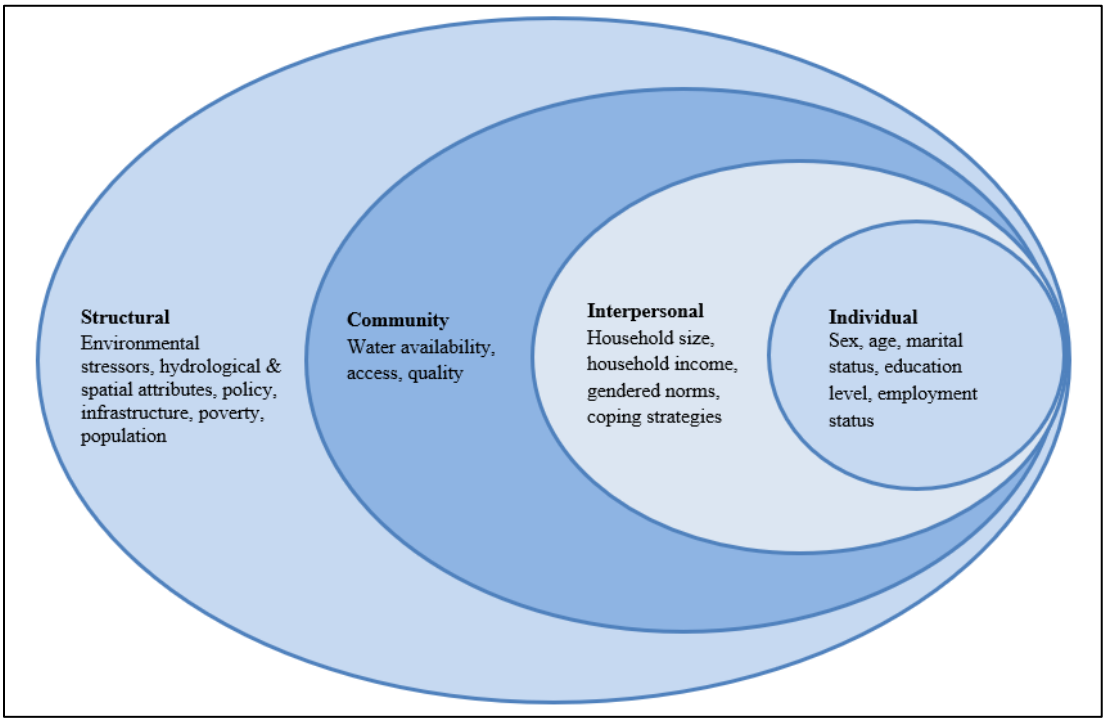


Figure 2.1: The Socio-Ecological Model

At the individual level, factors include age, sex, education level, marital status, and employment status. At the interpersonal level, factors like income level and household size determine the availability of resources and vulnerability. At the community level, there are shared or communal resources and influences, which in this study, are conceptualized as the proximal determinants. Proximal determinants refer to the actual dimensions or manifestations of water insecurity that lead to the experience of the phenomenon at the household level including availability, access and quality issues; for example, distance to water sources and water safety. At the structural level there

are distal determinants which comprise the underlying drivers of water insecurity including environmental/ecologic and structural factors like drought, floods, spatial attributes, poverty, governance and infrastructure.

The SEM provides an appropriate theoretical foundation for this study because water insecurity and HIV treatment outcomes are shaped by interacting influences operating at multiple levels and structural contexts. The SEM allows for the examination of broader determinants such as poverty, infrastructure, governance, environmental variability, and gendered norms. By situating drivers of water insecurity and HIV vulnerability across nested levels of influence, the model supports a structured analysis of how upstream structural factors, in this case, drivers and dimensions, translate into downstream health consequences, the HIV treatment outcomes. The model therefore offers a coherent framework for organizing the determinants examined in Objective 1 and for contextualizing the association analyses in Objective 3.

Guided by the SEM, the following section synthesizes existing literature on the determinants of water insecurity, distinguishing between the underlying drivers that generate vulnerability, and the dimensions through which water insecurity manifests. Understanding both components is critical for situating water insecurity as a structurally produced phenomenon rather than merely a household-level deprivation.

2.1.3 Socio-ecological drivers of water insecurity

Water insecurity arises from a complex interplay of environmental, societal, technological, and governance factors (World Bank, 2021). The global water crisis exhibits regional variations, influenced by diverse factors such as demand patterns, supply availability, infrastructure development, and governance practices (Veettil et al., 2022). Furthermore, water security often intersects with other security concerns, including energy security, food security, housing security, effects of climate change, and national security (World Bank, 2021). Some empirical evidence from low- and middle-income countries (LMICs) further highlights rapid population growth, urban expansion, and economic development as key structural pressures shaping water demand and scarcity (Mulwa et al., 2021). Understanding these drivers is important because it makes it possible to situate water insecurity within broader structural contexts as opposed to looking at it as a household-level condition only.

This section synthesizes literature on the socio-ecologic drivers of water insecurity, focusing on evidence from LMICs, with an emphasis on Sub-Saharan Africa and South Asia. The drivers have been organized across structural, community, interpersonal, and individual levels of influence, as guided by the SEM. It is important to note that few empirical studies have been explicitly designed to identify or investigate the determinants of water insecurity as their primary focus. Instead, much of what is known about these determinants has been drawn from broader research on water access, sanitation, health, nutrition, or gender dynamics, where the underlying causes of water insecurity are discussed peripherally or embedded within other objectives. As a result, the literature on determinants tends to be fragmented, context-specific, and often inferred from thematic findings rather than systematically assessed. This fragmentation points to the need for a structured, socio-ecologic analysis that integrates drivers across levels rather than examining them in isolation.

2.1.3.1 Structural-level drivers

At the structural level, water insecurity is determined by environmental stressors, spatial attributes, infrastructure systems, governance arrangements, large-scale pollution, population dynamics, and entrenched socioeconomic inequalities. These drivers operate beyond the household and community, reflecting macro-level conditions that determine how water resources are distributed, regulated, and sustained over time.

Environmental stressors

Environmental stressors constitute a central structural driver of water insecurity. Climate variability, including recurrent droughts and flooding, disrupts water availability, reliability, and safety across many LMICs (UNICEF, 2021; WHO, 2023a). Changes in precipitation patterns and increasing frequency of extreme weather events (EWEs) alter hydrological cycles, reducing predictability of both surface and groundwater resources (Nkiaka, 2022; Sun et al., 2022). Rather than representing isolated events, unpredictable droughts and floods reflect broader shifts in climatic systems that intensify seasonal instability and undermine long-term water planning.

Lack of precipitation over time is widely documented as a major contributor to water scarcity. Prolonged dry periods reduce river flow volumes, diminish surface water availability, and limit groundwater recharge, increasing competition for limited water resources (Greve et al., 2018). On the extreme opposite, flooding, although often associated with temporary water excessiveness, can likewise exacerbate water insecurity. Floodwaters frequently damage infrastructure, overwhelm

drainage systems, displace people, and contaminate water sources through runoff and sewage overflow (Njogu, 2021; Suhr & Steinert, 2022; WWAP, 2018). This is to say that hydrological extremes, whether characterized by scarcity or excess water availability, can both destabilize water systems and increase vulnerability to water insecurity.

Geographic and topographic characteristics further shape and sometimes exacerbate exposure to these environmental pressures, for example, low-lying areas and floodplains are more susceptible to inundation (Mulu et al., 2025). The study by Mulu (2025) used a multi-criteria decision analysis and generated a flood vulnerability map through weighted overlay analysis, and identified slopes and soil types as some of the vulnerability factors for flooding. Importantly, proximity to large water bodies does not necessarily guarantee secure access. Where treatment systems, distribution networks, or pollution controls are inadequate, nearby lakes and rivers may remain unsafe or inaccessible for domestic use (County Government of Kisumu, 2023; Omemo & Lutta, 2024; Roegner et al., 2020). On the other hand, arid and semi-arid regions face chronic water scarcity, also limiting access (Bensen, 2025; Eden Green, 2023).

In areas bordering Lake Victoria, environmental abundance coexists with contamination and infrastructural constraints, illustrating that water security depends not only on physical presence but also on system functionality. Although environmental stressors are widely documented, many studies treat climate variability and geographic or spatial attributes as external or background factors rather than examining how they interact with infrastructure capacity, governance systems, and socioeconomic inequalities to produce water insecurity. This interaction suggests that environmental drivers operate within broader structural contexts rather than functioning independently.

Overall, the literature on climate variability, extreme weather events, and geographic context demonstrate that water insecurity is often rooted in macro-level environmental conditions that operate beyond household control, shaping baseline vulnerability upon which other socio-ecologic determinants interact. A buildup of the interacting problems brought on by climate-related extreme weather phenomena, particularly flooding and drought, and their direct cause of water insecurity increases the health risks for PWH. In low resource settings, these problems may affect their ability

to access health facilities and lead to missed clinic visits but may also cause treatment interruptions and poor adherence to ART, including the chance that they will experience treatment failure.

Over-extraction, hydrological stress, and environmental degradation

Beyond naturally occurring environmental stressors, unsustainable human-driven extraction of freshwater resources has been identified as a major anthropogenic driver of water scarcity (Greve et al., 2018). Where groundwater extraction exceeds natural recharge rates, aquifer depletion and long-term water deficits occur (Codur et al., 2015). In some contexts, increased agricultural and industrial demand further accelerates depletion, particularly in rapidly urbanizing regions (Mulwa et al., 2021). Importantly, over-extraction reflects structural governance failures such as weak regulation, inadequate monitoring, and limited enforcement rather than household-level misuse.

Hydrological stress constitutes a distinct structural determinant of water insecurity. Hydrological stress arises when water demand persistently exceeds available supply within a given basin or aquifer system (Greve et al., 2018). Unlike over-extraction, which is a driver, hydrological stress captures the resulting imbalance within the water system. According to Greve et al. (2018), the condition may emerge not only from excessive abstraction, but also from limited water availability due to low rainfall, recurrent droughts, or reduced recharge capacity. Rapid growth of the population, expansion and intensification of agricultural activities, and the expansion of industries further increase pressure on surface and groundwater resources (Mulwa et al., 2021). Hydrological constraints may also reflect inherent aquifer characteristics. Certain geological formations yield limited recharge or low transmissivity, restricting groundwater accessibility even in the absence of over-extraction (Bon et al., 2022; Ojoawo & Adagunodo, 2023). In some contexts, groundwater sources may contain naturally occurring chemical contaminants, including fluoride, which compromise potability despite apparent availability of water (Onipe et al., 2021; Schimpf & Cude, 2020). This attests to the multidimensional nature of water insecurity; so that water availability alone is not enough: the quality of the water is just as important. Although hydrological stress is often discussed within broader water scarcity discourse, it is rarely analyzed explicitly as a determinant of household-level water insecurity. This disconnect underscores the importance of linking basin-level water dynamics with community and household experiences of water availability, access, reliability, and safety.

Environmental degradation, including deforestation, poor land management, and wetland encroachment, also affects watershed integrity and groundwater recharge (Rukundo & Dogan, 2019). These macro-level environmental processes shape water availability across entire regions and may persist despite localized interventions.

Water infrastructure deficits

Water infrastructure deficits are among the most consistently documented structural drivers of water insecurity in low- and middle-income settings (Ahmed et al., 2021; Kangmennaang et al., 2020a; Pienaah et al., 2024). While hydrological conditions highlighted above may determine the physical availability of water, infrastructure systems determine whether that water can be safely abstracted, treated, stored, and distributed to households. Further, inadequate piped water networks, aging distribution systems, malfunctioning boreholes, limited storage capacity, and insufficient treatment facilities constrain reliable water access (UNCTAD, 2023). Even in areas with relatively abundant water resources, weak infrastructure can produce chronic supply interruptions, forcing households to rely on alternative or informal sources. Infrastructure breakdowns are particularly consequential in rapidly urbanizing regions, where service expansion often lags behind population growth (Mulwa et al., 2021; Pienaah et al., 2024).

Infrastructure quality also affects water reliability. Intermittent supply systems may increase contamination risk due to pressure fluctuations and pipe leakage, particularly in informal settlements where connections are unregulated (Adams et al., 2022; Shinyemba & Cloete, 2023). In rural settings, non-functional boreholes and poorly maintained communal water points similarly disrupt access, quality, and increase travel distances for water collection (Ahmed et al., 2021).

Importantly, infrastructure deficits reflect structural investment patterns and maintenance capacity rather than individual household behaviors. Chronic underinvestment, weak maintenance systems, and fragmented service delivery frameworks contribute to persistent service gaps (World Bank, 2021). Thus, infrastructure limitations represent institutional and structural vulnerabilities that mediate the relationship between environmental water availability and household water security.

Water governance failures and regulatory gaps

Governance structures play a central role in determining water security outcomes. Apart from environmental and infrastructural constraints, water insecurity is frequently rooted in institutional

weaknesses, fragmented regulatory systems, and inadequate policy implementation (World Bank, 2021). Governance determines how water resources are allocated, monitored, protected, and financed, thereby influencing both availability and equity in access. Weak regulatory oversight may permit unsustainable groundwater abstraction, unregulated informal water vending, and inadequate enforcement of water quality standards (Miller et al., 2020).

In many low- and middle-income settings, overlapping institutional mandates and limited coordination between national and local authorities further constrain effective water management (Veettil et al., 2022). Where institutional capacity is weak, even well-designed policies may fail to translate into improved service delivery. Governance failures also influence resource prioritization and infrastructure investment. Politically marginalized or geographically peripheral communities may receive limited service expansion, reinforcing spatial inequities in water provision (World Bank, 2021). In such contexts, water insecurity reflects not only environmental scarcity or infrastructural deficits, but also systemic inequities embedded within institutional arrangements. Even in a country like Kenya where water services are devolved, the services only go as far as the urban boundaries; and this does not always include informal urban settlements.

Importantly, governance challenges interact with environmental stressors and infrastructure systems. Climate variability may strain already fragile institutions, while inadequate regulation may exacerbate pollution, over-extraction, inequitable service provision, and infrastructure deterioration. Thus, governance operates as a structural determinant that mediates how policy, environmental and hydrological pressures translate into lived experiences of water insecurity.

Pollution and large-scale contamination

Pollution and large-scale contamination represent structural drivers that compromise water safety even where physical availability is sufficient. Industrial discharge, agricultural runoff, untreated wastewater, and solid waste mismanagement contribute to widespread degradation of surface and groundwater sources (Odhiambo et al., 2023; Roegner et al., 2020). In regions surrounding Lake Victoria, for example, nutrient loading, sewage discharge, and urban effluent have reduced water quality and increased microbial contamination risks (AFD, 2021; County Government of Kisumu, 2023).

Contamination at scale reflects systemic failures in environmental regulation, wastewater treatment infrastructure, and enforcement of quality standards (Miller et al., 2020). As a result, water insecurity may manifest not only through scarcity but also through reduced potability and increased health risks. The presence of water in close proximity does not necessarily translate into safe or usable supply, particularly in rapidly urbanizing settings where pollution control mechanisms are weak. Large-scale contamination therefore operates as a structural determinant by reducing the effective usability of available water resources and increasing dependence on unsafe, unaffordable, or informal alternatives.

Spatial inequities in the distribution of resources

Water insecurity is unevenly distributed across geographic and socioeconomic contexts. Spatial inequities in infrastructure development, service provision, and regulatory enforcement contribute to disparities in water access between urban and rural regions, formal and informal settlements, and central versus peripheral communities (Pienaah et al., 2024; World Bank, 2021).

Rapid urban expansion often outpaces infrastructure investment, resulting in widening demand-supply gaps, particularly in informal settlements where service provision may be irregular or absent (Mulwa et al., 2021). Rural areas may similarly experience chronic underinvestment, increasing reliance on unimproved or seasonal sources.

Spatial inequities illustrate that water insecurity is shaped not only by environmental conditions but also by patterns of development and resource allocation. Communities situated near major water bodies may nonetheless experience insecure access due to infrastructural and institutional limitations, underscoring the importance of examining geographic marginalization as a structural driver.

Structural poverty and economic marginalization

Structural poverty and economic marginalization further shape water insecurity at macro levels. Limited fiscal capacity constrains public investment in infrastructure development, maintenance, and regulatory oversight (World Bank, 2021). Broader economic inequalities influence which regions receive service expansion and quality improvements. At the structural level, poverty reflects systemic deprivation rather than solely household income insufficiency. Chronic

underinvestment in water systems, inadequate subsidy frameworks, and unequal distribution of development resources reinforce persistent water insecurity across marginalized populations.

Structural poverty interacts with environmental stressors, governance limitations, and infrastructure deficits, amplifying vulnerability to both scarcity and contamination. Thus, water insecurity must be understood within broader political and economic contexts that shape long-term resource allocation and distribution.

Population growth, migration, and displacement

Population growth, migration, and displacement contribute to increasing pressure on water systems and are increasingly recognized as structural determinants of water insecurity (Achore et al., 2020; Sun et al., 2022). Rapid population growth increases demand for freshwater resources, while urbanization and rising living standards further intensify water consumption. Global projections estimate that the world's population will reach 9.8 billion by 2050, with nearly half living in urban areas (Ritchie & Roser, 2018). This trend places significant strain on local communities to meet the escalating demand for freshwater, particularly in regions prone to drought (Boretti & Rosa, 2019).

Migration and displacement can further concentrate demand for water in specific locations. Populations in displacement camps or host communities often face limited access to water and sanitation services, increasing pressure on already constrained local systems (Schoch & Lakner, 2020). According to the International Federation of Red Cross and Red Crescent Societies (IFRC), 98% of disaster displacement in the year 2020 was as a result of climate and weather hazards. The Intergovernmental Panel on Climate Change stated that climate change plays a role in specific catastrophic events like storms, floods, and droughts. Additionally, factors such as population growth, population density, poverty, and armed conflicts are also contributing to a shift in the patterns of disasters. Communities worldwide are grappling with the distressing humanitarian consequences stemming from displacement caused by climate-related factors. These consequences arise from events like rising sea levels, droughts, intense heatwaves, floods, and storms. The most vulnerable and marginalized are disproportionately bearing the brunt of these impacts; and the detrimental effects of climate change are already exerting their influence on the well-being and livelihood activities of vast communities across the globe (IFRC, 2021).

Studies from SSA have shown the relationship between population pressure and water insecurity. For example, a study identified population growth as a key driver of water stress in developing regions (Nkiaka, 2022). In Ghana, a widening demand-supply gap was associated with water insecurity especially in rural and peri-urban areas (Pienaah et al., 2024), and in some neighborhoods, residents resorted to illegal or informal coping mechanisms to deal with water insecurity (Achore & Bisung, 2023).

Despite the clear connection between population dynamics and water insecurity, relatively few studies focus on population growth as an independent driver of water insecurity. The tendency is to treat it as an underlying social factor, rather than an explicitly measured determinant. This highlights a gap in understanding how demographic pressures interact with infrastructure, governance, and environmental stressors to determine water insecurity.

In summary therefore, despite the growing recognition of the multifaceted nature of water insecurity, most existing studies have examined its determinants within broader investigations of health, equity, access, gender, or environmental issues. While research has identified key drivers such as poor infrastructure, weak governance, environmental variability, gender inequities, contamination, and poverty, these determinants are often explored in isolation, without an integrated framework or consistent measurement. Moreover, many studies rely on cross-sectional quantitative or qualitative data that limit causal inference, and few directly link specific determinants to long-term health outcomes. Critically, none of the reviewed studies specifically examine how these determinants interact to shape water insecurity among PWH, a population for whom consistent access to safe water is essential for treatment adherence, nutritional support, hygiene, and mental well-being. There is a dearth of research focusing on communities situated next to major water bodies such as Lake Victoria, the second largest freshwater lake by surface area in the world, where proximity to that water source does not guarantee safe or reliable access. These gaps point to the need for context-specific, interdisciplinary research that assesses the socio-ecological drivers of water insecurity among PWH in settings where environmental abundance co-occurs with structural resource deprivation.

While structural drivers shape the broader environmental, institutional, and economic conditions of water systems, community-level factors determine how these broader forces manifest within local water environments where households obtain water.

2.1.3.2 Community-level drivers

Community-level drivers represent the immediate environmental and infrastructural conditions within which households obtain water. These drivers shape how broader structural determinants like climate variability, governance systems, and infrastructure investment manifest locally. In many settings in LMICs, the characteristics of local water systems strongly influence the availability, accessibility, reliability, and safety of water sources used by households.

Distance to water sources remains a widely documented determinant of water insecurity. Communities that rely on distant water points often experience greater time and labor burdens associated with water collection, which may limit the quantity of water available for domestic use and increase exposure to health and social risks (Pienaah et al., 2024). Long collection times may also reduce water use for hygiene and sanitation, thereby increasing vulnerability to water-related illnesses (WHO, 2023b). These burdens are often compounded in settings where households depend on a limited number of communal water points.

The type of water source available within a community can be a determinant of water insecurity. Households drawing water from improved sources such as piped systems or protected boreholes generally experience greater reliability and safety compared to those relying on unimproved sources such as rivers, shallow wells, or surface runoff (Hassan et al., 2025; WHO, 2023b). However, even improved sources may provide intermittent supply, particularly in rapidly growing urban and peri-urban areas where service expansion has not kept pace with population growth (Belmeziti, 2025). As a result, households often diversify their water sources, shifting between multiple options depending on seasonal availability, cost, and reliability.

The functionality of shared water infrastructure also plays a critical role in determining community water security. In a study conducted in Nairobi on resilient water provision focusing on wells and boreholes, it was found that malfunctioning boreholes, damaged pipes, and poorly maintained communal taps can disrupt supply and increase reliance on alternative or informal sources (Akallah, 2022). Such disruptions may increase the time required to obtain water and contribute to overcrowding at remaining functional water points, further intensifying collection burdens within affected communities.

Water quality at the community level is another key determinant of water insecurity. Contamination of shared water sources through microbial pathogens, agricultural runoff, or sewage intrusion may compromise the safety of water supplies even when sources appear physically accessible (Ahuja, 2021; Schimpf & Cude, 2020; SPIW, 2023). In such contexts, communities may face a paradox of water presence but limited potable supply. Seasonal variability can further intensify these challenges. During dry periods, reduced water availability may force communities to rely on unsafe or temporary sources, while flooding events may contaminate previously safe water points through surface runoff or sewage overflow (Belmeziti, 2025; Hassan et al., 2025).

Despite growing recognition of these community-level determinants, much of the literature on water insecurity continues to emphasize household or individual experiences without sufficiently examining how characteristics of shared water systems shape exposure to risk. Greater attention to community-level infrastructure functionality, source diversity, and local contamination pathways is therefore essential for understanding how structural drivers translate into everyday water insecurity.

2.1.3.3 Interpersonal (Household)-level drivers of water insecurity

At the interpersonal level, household socioeconomic conditions and internal dynamics influence the ability of households to secure adequate water for daily needs. These drivers shape how families navigate constraints within their local water environments and determine their capacity to cope with water scarcity or unreliable supply.

Household income is a particularly important determinant of water access. A multiple case study conducted in Ghana on water insecurity and coping found that one, financial resources influence whether households can afford to purchase water from vendors, pay connection fees for piped systems, or invest in storage and treatment technologies; and two, where formal water services are unreliable, households with greater economic resources are able to supplement supply through private vendors or alternative sources, while poorer households remain dependent on limited or unsafe options (Achore & Bisung, 2023). The built environment of the home is closely related to the household's economic capacity. These built environment conditions also determine water access and use (Beard & Mitlin, 2021). Evidence from work done in the Global South shows that

households connected to piped water systems also frequently experience intermittent supply, which causes water insecurity by undermining reliability (Beard & Mitlin, 2021). What this means is that access to infrastructure alone does not guarantee water security for households. In contrast, evidence from rural Zambia shows that access to piped water substantially reduces time spent fetching water, enabling greater participation in productive and caregiving activities (Winter et al., 2021). In Kenya, water insecurity is multidimensional and unevenly distributed, with affordability and sufficiency emerging as key drivers at the household level, and disparities evident across residence, dwelling type, and socioeconomic status (Njoroge et al., 2024).

Multiple studies from SSA have demonstrated that household size also influences vulnerability to water insecurity. For example, evidence from Ethiopia, Ghana, and Nigeria has shown that larger households require greater volumes of water to meet basic domestic needs, including drinking, cooking, hygiene, and sanitation. Where water supply is limited or costly, increasing household size may intensify competition for available water resources and exacerbate the time and labor required for water collection (Oyerinde & Jacobs, 2022; Pienaah et al., 2024). Similarly, an analytical cross-sectional study done in Kisii, Kenya, indicated that household size was a determinant of water insecurity (Ondieki et al., 2022). These pressures may be particularly pronounced in multigenerational households or households with high dependency ratios.

In addition to economic factors, household decision-making processes and gendered divisions of labor influence water management practices (Cole et al., 2024; Tallman et al., 2023; WHO/UNICEF, 2023a). A systematic review focusing on linkages between water and gender dynamics showed that in many contexts, responsibility for water collection and management falls disproportionately on women and girls (Pouramin et al., 2020). This gendered burden may increase time poverty and expose women to physical strain or safety risks associated with long travel distances to water sources. At the same time, according to two other systematic reviews, household decision-making power may influence how water resources are allocated within the home, including decisions related to water purchasing, storage, or treatment practices (De Guzman et al., 2023; Ho et al., 2021).

Studies indicate that household coping strategies also play an important role in mediating water insecurity. According to Beard & Mitlin (2021), households tend to adopt coping strategies like

buying water from vendors, storing water when there is supply, or using several different supply sources like purchasing from water kiosks in a bid to cope with unreliable supply. Such strategies create disproportionate financial burdens on poorer households that have no choice but to pay higher prices for water obtained through informal markets (Beard & Mitlin, 2021). Achore and Bisung (2023), agree with this finding in their multiple case study in Ghana, that families may adopt a range of adaptive responses when faced with unreliable supply, including rationing water, storing water during periods of availability, switching between sources, or relying on social networks for temporary access. While such strategies may mitigate short-term shortages, they may also introduce new risks, particularly where stored water becomes contaminated or where reliance on informal sources exposes households to unsafe water.

Although household-level factors are widely recognized in water insecurity research, many studies treat households as isolated units of analysis without fully accounting for how household coping capacity is shaped by broader structural and community conditions. It is evident from the literature that household-level water insecurity emerges from the interaction of economic capacity, infrastructural conditions, and service reliability. These factors determine not only access to water, but also the time, cost, and labor required to secure it, with important implications for health, gender equity, and overall well-being. Thus, it is essential to understand those interactions as a way for situating household experiences of water insecurity within the wider socio-ecological context.

2.1.3.4 Individual-level drivers of water insecurity

At the individual level, demographic and socioeconomic characteristics influence vulnerability to water insecurity and shape how individuals experience and respond to water-related constraints. These characteristics affect access to economic resources, mobility, decision-making power, and health status, all of which can influence exposure to water insecurity.

Sex is one of the most consistently documented individual determinants of water insecurity. In a mixed-methods study conducted in Tanzania, findings showed gender as one of the sociodemographic factors associated with low access to water (Ngayaga et al., 2025). According to a recent report by the WHO and UNICEF, women and girls bear primary responsibility for water collection in many regions, which may require long travel distances and significant time

investment (WHO, 2023d). This responsibility can have important implications for education, economic participation, psychosocial, and physical well-being, particularly where water sources are distant or unreliable (Cooper-Vince et al., 2018; Pouramin et al., 2020; WHO/UNICEF, 2023b).

Age may also influence vulnerability to water insecurity. Older adults and young children may face additional challenges in accessing water due to reduced physical mobility or increased dependence on caregivers (Achore et al., 2025). Educational attainment and employment status may further shape individual experiences of water insecurity. Higher levels of education may influence awareness and adoption of water treatment or hygiene practices, while stable employment may increase financial capacity to secure alternative water sources during periods of scarcity (Ngayaga et al., 2025). Conversely, unemployment or unstable income may limit an individual's ability to cope with rising water costs or unreliable supply (Achore & Bisung, 2023).

Despite the relevance of these individual characteristics, research on water insecurity increasingly recognizes that individual vulnerabilities are embedded within broader household, community, and structural contexts. Individual experiences of water insecurity therefore reflect the cumulative effects of multiple interacting determinants operating across the socio-ecological system.

These socio-ecological drivers illustrate that water insecurity is shaped by interacting determinants operating across multiple levels. Structural conditions influence the availability and governance of water resources, community-level factors shape the reliability and safety of local water systems, household characteristics determine coping capacity, and individual characteristics influence vulnerability and lived experiences of water access. Understanding these interacting levels is therefore critical for explaining how water insecurity emerges and how it ultimately affects health outcomes. Further, these socio-ecological drivers illustrate that water insecurity is not solely a product of physical water scarcity but arises from interacting determinants that influence the availability, access, and quality of water. Structural and environmental conditions largely shape the availability of water resources, community-level infrastructure and source characteristics influence physical access and reliability, while household and individual factors affect the ability to secure safe and sufficient water. Examining water insecurity through this multi-level lens

therefore provides a more comprehensive understanding of how structural and social conditions interact to shape everyday water experiences and associated health outcomes.

2.1.4 Dimensions of water insecurity

2.1.4.1 Water availability

Water availability refers to the distribution and the physical quantities or physical existence of water that are present in the environment (Workman & Ureksoy, 2017; Young et al., 2021). In this regard, water may be scarce or available in excess. It also means that water availability, though a requirement, may not be a guarantee for water access. It is also the amount of accessible water that can be put to various uses and is determined by physical supply quantities, quality or safety of water sources, climate, infrastructure, land use and population (Koyratty et al., 2021; WWAP, 2018). The number and types of water sources in a community is one way of establishing water availability. Water availability has variable extremes as dictated by drought and flooding disasters (WWAP, 2018), which respectively create water scarcity or excessiveness.

Water scarcity refers to the shortage of freshwater resources or a deficit in the availability of freshwater resources for both human and environmental requirements; and depicts considerable spatiotemporal disparities (Sun et al., 2022). It is influenced by both demand and supply; and determined by water quality; to the extent that improving its quality makes it possible to recycle the water (WWAP, 2018). Water scarcity can be physical or economical (Sun et al., 2022) but in low resource regions, there is usually both physical and economical scarcity. Physical water scarcity relates to the shortage of natural water resources whereas economic water scarcity has more to do with access problems which may be due to poor water infrastructure or unaffordable safe water costs especially in low-resource areas (Sun et al., 2022). According to Greve et al., (2018), the greatest driver of water scarcity in many parts of the world has been the increased extraction of freshwater in the 20th Century and early decades of the 21st Century (Greve et al., 2018).

Water excess or overabundance as a component of water availability is rarely discussed under water insecurity, yet it presents an immediate threat to the lives and well-being of affected communities. Water excessiveness has been discussed mostly as overabundance or flooding, which occurs due to above average precipitation, burst riverbanks, or sometimes back-flow from

lakes where they are present in a community. According to Suhr and Steinert (2022), more than 2 billion people have been impacted by floods globally over the last 2 decades with devastating consequences to health (Suhr & Steinert, 2022). According to the results of a review conducted in SSA by these authors, flooding increases the risk of several infectious diseases, including malaria, cholera, viral encephalitis, some viral hemorrhagic fevers, trypanosomiasis and taeniasis. The review however does not discuss how excess water availability may impact HIV health outcomes, which shows a gap in the existing literature on the HIV health outcomes of flooding in SSA.

In Kenya, Lake Victoria which lies next to the study location, has experienced rising levels that lead to backflows and flooding, and is projected to continue rising in the foreseeable future (Aura et al., 2020). Overall, flooding in communities bordering rivers and lakes has consequences on food security (Baeribameng et al., 2022), health, livelihoods, settlement, infrastructure, and biodiversity (Obando et al., 2016), as well as on water security.

Seasonal water availability is a critical factor contributing to water insecurity, affecting between one and two billion people each year, especially in regions with distinct wet and dry seasons. In many parts of the world, water sources experience fluctuations in quantity and quality throughout the year, leading to periods of scarcity. Climate change exacerbates these seasonal variations, impacting the hydrological cycle to affect water resources (Stringer et al., 2021), resulting in changing precipitation patterns that lead to extended droughts or intense rainfall events that cause floods. According to Mekonnen & Hoekstra (2016), large disparities and seasonality in spatial and temporal availability and demand for water are responsible for water scarcity at the global level.

In Africa, water security is a significant challenge with seasonal changes in water availability being linked to food insecurity, malnutrition, and poverty, particularly in rural areas (Stringer et al., 2021). In a study conducted to investigate how seasonality of water source affected enteric infections in under 5 children in South Africa, it was concluded that in regions with bimodal rainfall seasons especially during excessive water availability, waterborne and water-related infections abound (Nguyen et al., 2021). According to a separate qualitative study on seasonality, water use, and management of water systems conducted in Zambia, Ghana and Kenya, Kelly et al. (2018), concluded that seasonality significantly impacts the sustainability of rural, community-managed water systems in sub-Saharan Africa. The availability of water sources, water system breakdowns, resource mobilization, committee activity, and external support are all influenced by

seasonal changes, affecting water system management (Kelly et al., 2018). These studies are relevant for understanding how seasonality affects water availability in Africa. However, the phenomenon has not been studied in one of the most important populations in the region: PWH, and how it may influence their health outcomes. Addressing water insecurity unidimensionally may not be effective because there are different dimensions to the problem, and it is important to identify the dimensions of water insecurity that are important and address those comprehensively.

2.1.4.2 Water access

According to Workman (2017), water access as a dimension of water insecurity refers to a demand-side construct that regards water as a commodity that is attainable by a household. It takes into consideration factors such as distance from water source and sufficiency of the water in meeting household needs. In concurrence, Young et al., (2021) refer to water access as answering the question "can one get to it?" Water access is not a physical phenomenon, but a complex dimension framed around structural and individual considerations. Whereas the water may be available in a nearby water body, other factors such as safety, road access, cost, or individual health may be a barrier to getting to the water. According to these authors, access in and of itself is necessary, but does not guarantee sufficiency for use. The CDC define water access as "drinking water from an improved source that is accessible at home, available when needed, and free from fecal and priority chemical contamination".

According to Koyratty et al., (2021), water access is regarded as both the physical delivery and economic access to water, with consideration given to distance to both drinking and non-drinking water sources, time taken to get the water, and financial costs incurred in getting the water. The terms "economic access" and "physical delivery" of water are interchangeable. Fetching time, distance to water points, and water costs are all tools for measuring water access. If households must go more than one kilometer or thirty minutes (return trip) to get water, their access to water is inadequate. The physical presence of water resources and/or related infrastructure that makes the water sufficiently accessible to homes determines the availability of water. The consistency or irregularity of the water supply is referred to as water reliability. Water may be inaccessible occasionally or seasonally, whether it is piped into homes or provided off-site. Spending 3% to 5% of a household's gross income on water makes it affordable (Koyratty et al., 2021). When

considering water access therefore, expenditure exceeding 5% of a household's total income on water means the water is expensive and access may be hindered.

2.1.4.3 Water Quality/Safety

Water quality is one of the main dimensions of water insecurity (Achore & Bisung, 2023). Globally, contaminated water continues to be an important cause of morbidity and mortality, particularly in LMICs (Prüss-Ustün et al., 2019). About 90% of all cases of diarrhea can be attributed to contaminated water and poor sanitation in the most impoverished regions of the world (WHO, 2024; Wolf et al., 2014). The way that water is used should reflect how well and safely it is used for drinking and other uses. The water's color, odor, and flavor can all be used to gauge its physical quality. Turbidity, chlorine levels, total dissolved solids, and bacterial coliform presence in the water are tested in order to assess the microbiological safety and physicochemical quality of the water. Different types of water sources are utilized as a stand-in for water safety and quality in low-income areas (Koyratty et al., 2021). For example, compared to surface water from streams or rivers, protected water sources like piped water, wells, and boreholes are regarded as being chemically and microbiologically safer. In concurrence, Wolf et al., (2014) assert that when there is an ample supply of quality, potable water at the household with effective sanitary conditions to safeguard against contact with fecal matter, optimal health benefits will be realized.

In their meta-ethnographic study on coping strategies for water insecurity, Achore et al., (2020) found that purchasing water from vendors from unsafe sources, and prolonged storage of water in anticipation of scarcity exposed the water to contamination and put consumers at increased risk for infection. In the County Integrated Development Plan (CIDP III) for Kisumu County, Lake Victoria is reported to be under a rising threat due to pollution caused by dumping of effluent and untreated sewage, as well as other forms of point and non-point sources of pollution. This polluted water finds its ways to consumers in various ways, including purchases from cart water vendors (County Government of Kisumu, 2023). A study conducted on the health of peri-urban fishing communities in Kisumu found that this population faced a growing threat from the use of Lake Victoria water which was contaminated with harmful algal blooms and microcystins (toxins produced by freshwater blue-green algae), with the levels of this latter surpassing safety limits for children and vulnerable populations. The study also reported that the household water treatment methods used in these communities were inadequate for the effective removal of the microcystins,

and at times, even exacerbated the concentration of the pollutants (Roegner et al., 2020). Additionally, another potential source for unsafe water was found to be shallow wells (Othoo et al., 2020), rivers, and urban streams draining into Lake Victoria (Odhiambo et al., 2023) that were contaminated by human and animal fecal matter, as well as inorganic/chemical pollutants. These authors' findings are congruent with earlier studies on water quality in Kisumu showing that "unregulated construction of pit latrines" and "high nitrate levels" create a "dual burden" of chemical and biological risk for immunocompromised individuals (Nyilitya et al., 2021; Othoo et al., 2020).

According to the CDC, nearly 1 billion people worldwide still rely on untreated water from streams, lakes, or hand-dug wells, while many others consume contaminated water from unsafe municipal systems or borehole wells. In recent years, decentralized solutions for water treatment at the point of collection or use, along with education to enhance water handling, storage, and hygiene practices, have emerged. These solutions offer significant health benefits similar to piped, treated water but at a fraction of the cost and time.

Despite growing recognition of these socio-ecological drivers and dimensions of water insecurity, limited research has examined how these determinants interact to shape water insecurity among adult PWH in high prevalence, climate-vulnerable settings such as western Kenya.

2.2 Lived experience of water insecurity

Apart from understanding the dimensions of water insecurity, it is important to also understand the lived experience of water insecurity (Lemaitre et al., 2023; Molden, 2019; Stevenson et al., 2016). The lived experience of water insecurity encompasses the daily struggles individuals face in accessing sufficient and safe water for their basic needs. It involves physical, economic, and social challenges impacting health, education, housing, and livelihoods. According to Jepson et al (2017), the lived experience of water insecurity is characterized by the lack of dependable access to enough water for everyday domestic requirements. However, this definition overlooks several critical dimensions. It fails to capture water quality (safety and potability), cultural acceptability (taste, odor, and source preferences), and the broader livelihood uses (small-scale agriculture, livestock), all which shape how people experience and cope with water shortages. Apart from that, the definition does not acknowledge the psychosocial burdens like stress, anxiety, stigma,

depression, and social conflict; nor does it account for episodic shocks (droughts, system breakdowns) versus chronic shortages. By omitting these aspects, it risks underestimating the full scope of water insecurity's impacts on health, well-being, and social relations. Therefore, while dimensions describe the measurable manifestations of water insecurity like water quality, lived experience captures its embodied, emotional, and relational consequences. For water insecure PWH who face heightened vulnerability from HIV and insufficient safe water for medication adherence and overall health and well-being, it is important to have a broader conceptualization of the lived experience of water insecurity.

While literature on water insecurity and how it affects health and well-being is available, there is insufficient in-depth knowledge and understanding of the lived experience of water insecurity among PWH within the context in which the phenomenon exists. Much of the existing literature is quantitative using cross-sectional designs, emphasizing measurable associations rather than experiential processes, with very few qualitative studies focusing on experiential processes among the general adult population of PWH on ART. In the study by Nagata et al. (2021), in western Kenya, it was found that among adult PWH, an association existed between water insecurity and poor HIV health outcomes, whereby the odds of sub-optimal viral suppression and recent opportunistic infections were higher among water insecure PWH. While the study speculated on the possible pathways for this association, it did not delve first-hand into the challenges experienced by water insecure PWH that would put them at increased risk for worse HIV health outcomes. As a cross-sectional analysis of baseline data from a larger randomized clinical trial (RCT), the study design was not intended to capture temporal dynamics, coping strategies, or contextual mediators that may shape these associations. A finding worth noting in this study was that the association of household water insecurity and CD4 count did not reach statistical significance, raising questions about whether biological indicators alone adequately capture the lived disruptions in treatment experienced by PWH. This points to a broader methodological limitation within the literature. While existing preliminary statistical measures quantify associations between these variables, they do not explain the processes through which water insecurity may disrupt engagement in HIV treatment, daily functioning, or psychosocial well-being. On the other hand, qualitative studies have tended to be focused on addressing water insecurity within specific sub-populations. For example, Collins et al (2019) explored the lived experiences of water insecurity amongst pregnant and postpartum women in western Kenya, and

demonstrated its consequences across physical, psychosocial, nutrition and economic domains, but without explicitly theorizing how these experiences translate into disruptions in HIV treatment. This leaves open a critical gap in understanding the cross-cutting, process pathways through which water insecurity shapes HIV treatment engagement across broader populations of PWH.

Challenges with water availability, access and quality have been demonstrated to influence the health and hygiene practices of PWH, such as hand washing, bathing and washing clothes. Additionally, these challenges have been found to worsen HIV health outcomes, whereby PWH experience difficulties with taking medication, and are more prone to diarrheal diseases, skin diseases and AIDS-defining illnesses (Collins et al., 2019; Miller et al., 2021a; Nagata et al., 2021). However, these studies largely treat hygiene behaviors as discrete outcomes rather than situating them within broader structural and economic constraints shaping daily life, and as a result, decisions and actions related to water challenges are not contextualized in relation to the lived trade-offs and constraints under which they are taken.

A systematic review on HIV-sensitive protections in East and Southern Africa found that better HIV outcomes, including prevention, retention, and adherence outcomes were associated with productive livelihood activities among vulnerable PWH (van der Wal et al., 2021). Water insecurity, however, can interrupt these livelihood activities, especially those dependent on availability of adequate water, such as farming. In situations where PWH are sick and unable to access water, they are unable to engage in income generating activities (IGAs) for their survival, which in turn may aggravate their HIV health leading to worse outcomes (WaterAid & AMREF, 2009). Findings from this study indicated that PWH had increased needs for clean and safe water due to their increased susceptibility to diseases and increased hygiene requirements. The increased need for water in turn increased demands on household resources generated from livelihood activities.

Water insecurity and poverty are intricately related, and efforts to mitigate water insecurity must be connected to those of poverty eradication (Adams et al., 2020). For water insecure PWH therefore, there remains limited understanding of how water insecurity shapes livelihood activities and household economic stability. Existing studies have not adequately explored whether this relationship is reciprocal or how PWH themselves interpret and negotiate these economic constraints in daily life.

Overall, the literature linking water insecurity and HIV among PWH remains fragmented across biological, behavioral, and livelihood domains. While quantitative studies establish association, they provide limited insight into how individuals experience, prioritize, and respond to water-related hardship in ways that may influence HIV treatment engagement and outcomes. To address this gap, a qualitative, phenomenological approach is necessary to center participant narratives and uncover the mechanisms through which water insecurity is translated into treatment disruption, psychosocial strain, and constrained agency.

Thus, to address the identified gaps in knowledge, and to explore the lived experience and pathways through which water insecurity could impede successful HIV treatment outcomes among adults on ART in objective 2 of this current study, the exploratory qualitative study adopted a phenomenological approach, described in detail in chapter three. Further, to deepen the understanding of how water insecurity could influence the health and well-being of PWH, this study adopted an interpretive framework developed by Amartya Sen and later expanded by Martha Nussbaum - the Capability Approach.

2.2.1 The Capability Approach

The Capability Approach (CA) offers a complementary theoretical lens for understanding the lived experience of water insecurity among adults on ART. While the SEM explains structural positioning, the CA focuses on how material deprivation constrains individuals' real freedoms to achieve valued functionings, such as maintaining health, adhering to treatment, preserving dignity, and sustaining social participation. In this study, water insecurity is conceptualized not merely as a lack of access to water, but as a constraint on capabilities that shape daily choices, coping strategies, and engagement in HIV care. The framework therefore provides an interpretive foundation for Objective 2, guiding the analysis of how participants experience and navigate water-related hardships.

According to Barreno-Alcade et al., (2024), the CA is a normative framework for evaluating individual well-being, social arrangements, and development outcomes. At its core, the approach shifts attention from resources or utility to what people are effectively able to "be" and "do", referred to as their capabilities. Nussbaum further articulated a list of ten central capabilities that should be supported for a life of dignity, including bodily health, bodily integrity, affiliation, and control over one's environment (Barreno-Alcalde et al., 2024).

The CA is framed around three core concepts: functionings, capabilities, and conversion factors.

- Functionings refer to the actual "beings and doings" a person is able to achieve, like being well-nourished, maintaining health, or staying safe.
- Capabilities represent the real freedoms and opportunities to achieve those functionings, with emphasis on choices and actual possibilities of pursuing different life paths as opposed to just having the formal right to do so.
- Conversion factors are the personal, social, and environmental conditions that influence how effectively a person can turn available resources into meaningful outcomes. These factors explain why two different people with access to the same resources can have vastly different capabilities.

The key strength of the CA is its focus on human diversity and agency, acknowledging that equal access to resources does not guarantee equal ability to achieve well-being (Egdell & Beck, 2020).

The CA, when applied to the lived experience of water insecurity, moves analysis beyond water as a physical resource to water as a condition for achieving vital human functionings. The question, therefore, is not merely whether adults on ART have water, but what they can actually do or be with the water they access. For PWH, clean and sufficient water is necessary for taking ART safely, maintaining hygiene to prevent opportunistic infections, preparing food to accompany medication, and preserving dignity through basic hygiene. When water is inadequate, inaccessible, contaminated, or expensive, these essential activities, and thus the capability to sustain HIV health, become constrained. Water insecurity, therefore, represents a deeper deprivation of capabilities: it limits the substantive freedoms through which PWH can pursue health, livelihood, and social participation.

Conversion factors further explain why the impact of water insecurity on PWH is particularly severe. Personal factors such as compromised immunity, chronic fatigue, and medication side effects mean that unsafe or insufficient water poses greater health risks to them than for the general population. Social factors, including stigma, discrimination, and gendered labor expectations, restrict access to safe water sources and increase vulnerability, particularly for women who carry the burden of collection. Environmental factors such as droughts, floods, and inadequate infrastructure make safe water unavailable or unreliable, compounding the stress and uncertainty

of daily survival. These intersecting conversion barriers reduce the ability of PWH to convert available resources into valued functionings like health, security, and self-sufficiency. Through the lens of the CA, water insecurity among PWH is understood not simply as an issue of resource scarcity, but as a constraint on health, dignity, and agency. Water insecurity therefore constitutes not only material deprivation but also a limitation of freedom, which is the freedom to sustain health, dignity, and social participation. Recognizing water security as a capability, rather than merely a commodity, signals the need for responsive, context-specific interventions that address both resource provision and the broader social and environmental conversion factors that shape how resources translate into well-being.

2.3 Association between water insecurity and HIV treatment outcomes

Although ART has substantially improved survival and transformed HIV into a manageable chronic condition, successful treatment depends on more than access to medication alone. Increasing evidence suggests that structural determinants of health, including water insecurity, play an important role in shaping HIV treatment outcomes among people living with HIV (Boateng et al., 2022; Nagata et al., 2021). Water insecurity is a multidimensional phenomenon encompassing inadequate availability, limited access, poor quality, unreliability, and unaffordability of water for domestic and personal needs. These dimensions may undermine HIV treatment by disrupting the daily conditions necessary for sustained adherence and engagement in care.

2.3.1 Water insecurity in the context of the HIV global to local burden

HIV remains one of the most significant public health challenges globally. An estimated 40 million people are currently living with HIV worldwide, with sub-Saharan Africa accounting for nearly two-thirds of this burden (UNAIDS, 2023a). Although the scale-up of ART has transformed HIV into a manageable chronic condition for many, important gaps remain. Millions of people still face interruptions in care, delayed diagnosis, or sub-optimal viral suppression. These gaps are not merely clinical failures; they often reflect deeper social and structural vulnerabilities that shape whether individuals are able to initiate and sustain lifelong treatment.

Sub-Saharan Africa bears a disproportionate burden, but it is not evenly distributed. Within countries, regional disparities persist, reflecting historical, economic, and infrastructural

inequities. In Kenya, the national HIV prevalence is approximately 3.1%, but this masks significant regional variations (NSDCC, 2024). Counties around Lake Victoria like Kisumu, Homa Bay and Siaya are also the regions with the highest burden of HIV in Kenya, with women having a greater burden at 14.9% compared to men at 8.6% in Kisumu County (NSDCC, 2024).

Kisumu County, located in western Kenya along Lake Victoria, carries a substantially higher prevalence of approximately 11.7%, nearly four times the national average. Despite improvements in ART coverage, a proportion of PWH in the county continue to experience challenges with sustained viral suppression and long-term treatment continuity.

In high-prevalence settings such as Kisumu County, ensuring access to ART is necessary but not sufficient. The daily realities of poverty, food insecurity, unreliable infrastructure, and environmental stressors shape how treatment is experienced and sustained. For PWH, adherence does not occur in isolation; it is embedded within broader material conditions that influence health, dignity, and survival. Among these structural determinants, water insecurity is increasingly recognized as an important yet under-addressed barrier to successful HIV treatment. Reliable access to adequate, safe and affordable water is essential for medication intake, food preparation, hygiene, management of opportunistic infections, and attendance at routine HIV clinic appointments. Consequently, disruptions in water availability, access or quality may compromise ART adherence, retention in care, viral suppression and overall HIV treatment success (Nagata et al., 2021; Nutor et al., 2024). Understanding HIV outcomes in such contexts therefore requires moving beyond biomedical indicators alone and examining the structural determinants that may enable or constrain treatment success. It is within this broader landscape that water insecurity emerges as a potentially critical, yet underexamined factor influencing HIV health trajectories.

According to the World AIDS Day Report (2022), rising new infections and AIDS-related deaths in many countries show that the World has faltered on the path towards ending HIV & AIDS. The gains hitherto made in HIV management are threatened by insufficient response and inequalities related to key populations, inequalities between children and adults, and inequalities in gender due to a culture of patriarchy and gender-based violence (GBV) which not only increases risk, but also creates a barrier in access to appropriate health care for women with HIV. Additionally, resources for AIDS response have become so inadequate as to make the eradication of HIV & AIDS as a public health threat by 2030 unlikely (UNAIDS, 2022a). While it highlights important issues

including financial resources that are slowing the progress towards eradication of HIV & AIDS, the report does not mention resource insecurities, and fails to explicitly recognize water insecurity as a structural resource constraint capable of disrupting ART adherence, retention in care, viral suppression, and other HIV treatment outcomes among PWH, particularly in water-stressed settings. This omission is important because HIV programmes are largely designed around the assumption that ART availability alone is sufficient for treatment success, whereas essential household resources such as water may determine whether treatment can be initiated, adhered to, and sustained over time.

2.3.2 Water insecurity and ART adherence

When initiating ART, it is crucial to educate patients about the advantages of ART and implement strategies to optimize their engagement in care and adherence to treatment (NIH, 2021). The primary objectives of ART are sustained viral suppression, immune restoration, reduction of morbidity and mortality, and prevention of transmission. Immediate or rapid initiation of ART after diagnosis has been shown to improve linkage to care and shorten time to viral suppression (NIH, 2021; Panel on Antiretroviral Guidelines for Adults and Adolescents, 2025). However, the effectiveness of ART depends not merely on initiation but on sustained access, adherence, and retention in care. Achieving these goals requires more than the availability of medication; it also depends on whether individuals possess the basic resources necessary to implement treatment recommendations in their daily lives. Increasing evidence suggests that structural resource insecurities, including inadequate access to safe and reliable water, may undermine optimal adherence despite ART availability by constraining medication intake, food preparation, hygiene, and attendance at scheduled clinic visits (Nagata et al., 2021; Boateng et al., 2022; Nutor et al., 2024).

Access and adherence to ART by PWH is vital for the prevention of HIV transmission to HIV-negative people (CDC, 2022), and ultimately to the eradication of HIV. Achieving viral suppression in PWH is of the highest significance. This is crucial because when individuals can suppress the virus, they are unable to transmit HIV to their uninfected partners (Thomford et al., 2020). In the recent past, the HIV eradication mantra has been the concept of undetectable = untransmittable (U=U); whose validity is dependent upon the maintenance of undetectable viral load by PWH. Literature also shows that PWH with no current sexually transmitted infection (STI)

who have maintained undetectable viral load for a period of 6 months do not transmit HIV (Eisinger et al., 2019). The achievement of undetectable viral load can take up to 6 months with adherence to ART. However, factors that lead to treatment interruptions and non-adherence can cause incomplete HIV RNA suppression and faster progression to AIDS; thus, reversing such achievements, since viral rebound tends to take place within 2 -3 weeks of ART stoppage (Eisinger et al., 2019). Consequently, identifying and addressing structural barriers that interfere with sustained adherence, including water insecurity, is essential for maintaining viral suppression and realizing the benefits of U=U.

Adherence to ART requires consistent medication intake, timely clinic attendance, and stable living conditions; and interruptions in treatment or non-adherence can lead to treatment failure (CDC, 2022; Thomford et al., 2020). Water insecurity may disrupt each of these requirements in various different ways. Inadequate water may limit the ability to swallow medication, prepare food needed to reduce medication-related side effects, maintain hygiene during illness, or prioritize clinic attendance when households must devote considerable time and resources to obtaining water. Water-related illnesses, displacement following flooding, and financial trade-offs associated with purchasing water may further compromise adherence by increasing competing household demands (Nagata et al., 2021; Collins et al., 2019; Boateng et al., 2022; Miller et al., 2021a). According to the WHO (2016) definition, treatment failure is defined as clinical (the occurrence of a new or recurring clinical event), immunological failure (a decrease in CD4 count back to the initial level), and virological failure (a viral load exceeding 1000 copies/mL), confirmed by two consecutive measurements taken three months apart with adherence support (WHO, 2016). Providing ongoing support for adherence to medication is crucial for patients experiencing virologic failure. Treatment interruptions or stopping the treatment can lead to a rapid viral RNA rebound thus virologic failure, immunological failure due to a massive drop in CD4 count, and a heightened risk of AIDS defining illnesses and faster progression to full-blown AIDS (AIDSinfo, 2020; WHO, 2021). A systematic analysis and meta-analysis of factors associated with treatment failure in low resource settings provided evidence that these outcomes often reflect more than presumed pharmacologic inefficacy; they are also the result of cumulative disruption in adherence to effective therapy (Lailulo et al., 2020). These observations suggest that treatment failure should not be viewed solely as a consequence of individual behaviour or pharmacologic limitations, but also as a manifestation of broader structural constraints that disrupt sustained

engagement in HIV care. Water insecurity represents one such constraint because it may interfere with adherence long before virologic, immunologic, or clinical failure becomes clinically apparent.

While the scaling up of ART has transformed HIV into a manageable chronic condition, adherence remains structurally mediated. Structural and material insecurities like poverty, stigma, unstable housing, and resource constraints are capable of disrupting medication routines and clinic engagement (Croome et al., 2017; Thomford et al., 2020). Water insecurity is increasingly recognized as one of these structural determinants because it directly influences the conditions under which ART is taken and HIV care is maintained. Nevertheless, compared with other structural barriers such as food insecurity, stigma and poverty, the contribution of water insecurity to ART adherence has received relatively limited empirical attention, particularly in sub-Saharan Africa where HIV burden and water insecurity frequently coexist (Nagata et al., 2021; Boateng et al., 2022). Consequently, further research is required to clarify the extent to which water insecurity contributes to poor ART adherence and subsequent HIV treatment outcomes.

2.3.3 Water insecurity and HIV treatment outcomes

Living with HIV has been associated with higher scores of water insecurity (Koyratty et al., 2021; Nagata et al., 2021). The Koyattry study however did not find a significant association between the water insecurity dimensions with HIV status. While the study examined associations between water insecurity and HIV status, the cross-sectional nature of its design introduces limitations on causal inference. As a result, these findings cannot establish the directionality of the relationship and risk implying causality in either direction without evidence of temporal ordering or underlying mechanisms. It also shows a gap in literature with regards to the way water insecurity has been studied among PWH. More importantly, HIV status alone provides limited insight into the clinical consequences of water insecurity among individuals already receiving ART. In the era of widespread ART availability, the more relevant question is whether water insecurity compromises HIV treatment success by disrupting adherence, retention in care, immune recovery, and viral suppression despite access to medication (Nagata et al., 2021). Investigating associations between water insecurity and HIV status is a valid line of inquiry; however, it does not capture the more clinically and programmatically relevant question in the context of widespread ART availability and access. Since effective treatment exists, the critical issue is not only whether water insecurity is associated with HIV status, but whether it can compromise treatment success among ART-

experienced individuals. Accordingly, greater attention should be directed towards understanding how water insecurity shapes HIV treatment outcomes among PWH, potentially undermining their prognosis despite access to effective treatment.

According to Nagata et al. (2021), HIV treatment outcomes are determined by both access to water and access to HIV care and treatment. Water insecurity may influence HIV treatment outcomes through multiple, interconnected pathways. Inadequate water availability, poor access, unreliable supply, and unsafe water quality may impair medication adherence, increase the risk of waterborne and opportunistic infections, reduce clinic attendance, disrupt food preparation required for medication intake, contribute to psychosocial stress, and undermine livelihoods needed to sustain long-term HIV care (Boateng et al., 2022; Miller et al., 2021a; Collins et al., 2019; Wutich, 2020). Through these mechanisms, water insecurity may ultimately compromise virologic, immunologic, clinical, and care engagement outcomes among PWH. To maintain the effectiveness of medication for PWH and prevent drug resistance and virologic failure, HIV care and treatment demand discipline and consistency (Orievulu & Iwuji, 2022). HIV treatment outcomes for water insecure PWH on ART may manifest singularly or in a combination that include missed clinic visits, sub-optimal viral suppression, low CD4 count, and AIDS-related illnesses (opportunistic infections).

According to the Panel on Guidelines for the Prevention and Treatment of Opportunistic Infections in Adults and Adolescents with HIV (2022), viral load monitoring and CD4 count are the surrogate markers of HIV disease progression and ART responses that have traditionally been used to monitor and manage HIV infection in PWH. Monitoring treatment is necessary because of the importance of maintaining PWH on first-line ART regimens, since treatment changes are not only expensive, but also reduce available options besides being prone to non-adherence and poor HIV treatment outcomes among PWH (Mugo et al., 2022). Consequently, monitoring HIV treatment outcomes provides an opportunity to evaluate whether structural determinants such as water insecurity translate into measurable differences in treatment effectiveness beyond ART access alone.

According to Thomford (2020), the success of U=U in SSA depends on the reduction of both structural and clinical barriers that hinder ART adherence, leading to sub-optimal adherence. Some examples of these barriers encompass limited access to effective and well-tolerated ART, medication shortages, stigma, the burden of taking multiple pills (polypharmacy), and insufficient

community support for sustained adherence (Croome et al., 2017). Although these structural barriers have been widely acknowledged, comparatively little attention has been given to water insecurity despite its potential to simultaneously influence medication adherence, clinic attendance, immune function, and susceptibility to opportunistic infections. Addressing this gap is particularly important in high HIV burden settings such as Kisumu County, where recurrent water-related challenges coexist with persistent gaps in HIV treatment outcomes. The following sections therefore examine the evidence linking water insecurity with specific HIV treatment outcomes, namely viral suppression, CD4 recovery, opportunistic infections, and retention in HIV care.

2.3.3.1 Sub-optimal viral suppression/virologic failure

According to the Panel on Guidelines for the Prevention and Treatment of Opportunistic Infections in Adults and Adolescents with HIV (2022), viral load is the most important indicator of sustained effectiveness of ART and should be measured in all PWH at entry into care, at initiation of therapy, and on a regular basis thereafter, yet, according to the NSDCC (2024), Kisumu County has a 17% viral suppression gap. Viral load monitoring is a marker of the response to and effectiveness of ART and provides information on the prognosis of HIV infection and disease. When there is a high viral load (≥200 copies/mL), it would indicate lack of viral suppression (MOH (NASCOP), 2022; OAR, 2021). The Panel recommends that in PWH who are on stable, suppressive ARV regimen, viral load measurement should be repeated every 3 to 4 months or as clinically indicated to ensure sustained viral suppression. The interval may be extended to 6 months for adherent PWH who have had continuous viral suppression for more than 12 months, who have stable immunologic and clinical status, and who are not at risk of treatment interruptions and non-adherence.

Incomplete suppression of viral loads can result from any cause of ART non-adherence, rather than specific aids defining illnesses, which often result from non-adherence, viral non suppression and virologic rebound; and subsequent treatment failure (Nagata et al., 2021). According to these authors, adult PWH in Kenya experienced worse HIV-related outcomes when their households had poor access to water. However, the study did not identify which dimensions of water insecurity were most influential, nor did it explore mechanisms linking water-related hardship to treatment disruption in the study area, which leaves a gap in our knowledge of the magnitude of the problem.

2.3.3.2 CD4 Count

According to the Panel on Opportunistic Infections in Adults and Adolescents with HIV, CD4 count is the most important laboratory indicator of immune function in PWH and the strongest predictor of HIV progression and survival. It provides information on the immunological status of an individual with HIV. After initiation of ART, CD4 count is useful in the determination of immunologic response, and a low CD4 count (<200) may indicate immunologic failure (AIDSinfo, 2020).

In low-income regions, changes in CD4 counts are vital for patient monitoring and assessment of ART effectiveness. CD4 counts are particularly crucial because PWH in these areas may lack access to regular viral load measurements (Mugo et al., 2022). Currently in Kenya, an individual on ART with a CD4 count <200 is considered as not responding well to treatment and having advanced HIV disease NASCOP, 2022). However, reliance on CD4 count alone may obscure behavioral and structural disruptions preceding biological decline. In this regard, CD4 measures capture downstream consequence rather than upstream instability in adherence or resource access.

2.3.3.3 AIDS-defining illnesses

AIDS-defining illnesses, also known as opportunistic infections, are specific infections and diseases that typically occur in individuals with advanced HIV infection and a severely compromised immune system. These illnesses are considered indicative of the presence of AIDS (WHO, 2021). The list of AIDS-defining illnesses has evolved over time as the understanding of HIV/AIDS has advanced, and it may vary slightly depending on the guidelines used.

Some examples of common AIDS-defining illnesses include tuberculosis, cryptococcal meningitis, Kaposi's sarcoma, and Pneumocystis pneumonia, and are more likely to appear when immune function declines. In PWH on treatment, these conditions often emerge following sustained treatment interruption or immunologic failure. Importantly, recurrent diarrheal illness and dehydration, conditions plausibly linked to unsafe water exposure, may exacerbate immune compromise and interfere with medication absorption among PWH. Yet few studies explicitly examine how water-related morbidity interacts with ART continuity. In addition, apart from ART non-adherence, few studies look at how water insecurity is associated with infections or opportunistic infections among PWH.

2.3.3.4 Missed clinic visits

Missed clinic visits refers to instances within the HIV treatment cascade where PWH fail to attend their clinic appointments where they are scheduled to receive treatment and medical monitoring related to their HIV health (Fazeli et al., 2020). Clinic visits are important as they constitute the core part of engagement in care for all PWH who have been initiated into care for purposes of accessing and adhering to ART towards viral load suppression and successful HIV treatment outcomes (Fazeli et al., 2020).

Scheduled clinic visits facilitate the monitoring of the progression of HIV in PWH. They are essential for conducting physical examinations, laboratory screening for CD4 counts and viral load measurements, and assessment of the individual's overall health to determine the effectiveness of ART, and where necessary, inform necessary treatment adjustments (Chamberlin et al., 2022). A systematic review and meta-analysis on retention of adult patients on ART in LMICs however showed that retention in care after one year of ART initiation was only 81%, which dropped to 65% three years after treatment initiation (Fox & Rosen, 2015).

Retention in care may be hampered by missed clinic visits, which in turn are influenced by financial insecurity, competing responsibilities, stigma, mental health challenges, and structural barriers (Fazeli et al., 2020; Howarth et al., 2022). However, water insecurity has rarely been examined as a potential driver of missed appointments. Time spent collecting water, illness from unsafe water, flood-related displacement, or resource trade-offs may plausibly disrupt clinic attendance, yet empirical examination remains limited.

The studies cited above, using a range of different designs, captured reasons for missed clinic visits, but water insecurity as a driver of missed clinic visits did not feature in most of the studies, which makes a case for further research on its role in retention in HIV care.

2.4 Gender and gendered differences in water insecurity and HIV burden

Worldwide trends in HIV indicate that women bear a greater HIV burden than men; with more women living with HIV (UNAIDS, 2023a). In many LMICs, there is a significant gendered disparity in both prevalent and incident HIV cases; with women and lately, adolescent girls being the drivers of new HIV infections (Girum et al., 2018; Sia et al., 2016; UNAIDS, 2024).

According to Sia et al., (2016), the primary reason for gendered differences in HIV prevalence is the differential effects of HIV risk factors between the sexes (Sia et al., 2016). Girum et al., (2018) concur with this assertion by explaining that the trend can be attributed to the increased susceptibility of HIV acquisition by women primarily because of biological, cultural, and socio-economic factors that heighten their vulnerability while reducing their access to quality care.

Water insecurity intersects with HIV/AIDS in complex and often gendered ways (WHO, 2017). The gendered burdens of HIV and of water insecurity are interconnected by interrelationships between labor, power, time, and psychosocial dynamics, and are further determined by social systems. In 80% of households in SSA, women and girls bear the responsibility for fetching water, usually from sources outside the home (WHO, 2023d). In Kenya, national survey data indicate that approximately 45% of women experience moderate to severe water insecurity annually (Young, 2021), underscoring the scale of this burden among women. Additionally, women's agency in decision-making and resource utilization are often low (Hanmer & Klugman, 2016), and when they fail to secure water for the household, they become especially vulnerable to harmful practices like intimate partner violence (IPV) (Choudhary et al., 2020; Odak, Young, et al., 2026). Additionally, within these households, women have diminished power to negotiate for equitable labor or make decisions on water resources, and yet, they are expected to ensure water supply at the household despite probable challenges with water access (Boateng et al., 2022; Hamill et al., 2023; Mutanda & Nhamo, 2024). According to these authors, there is intersectionality between gender, water/sanitation, and HIV management, to the detriment of the lives of women. To this extent, inadequate water infrastructure and health systems can likely exacerbate gendered burdens of both water insecurity and HIV care, leading to worse HIV treatment outcomes. But, considering PWH (male and female) who are water insecure, does the disproportionate burden of HIV and water insecurity borne by women translate into poorer HIV treatment outcomes among them, compared to men?

2.5 Food insecurity

Food insecurity can be defined as the inadequate access to safe, nutritious food of sufficient quantity and quality; or the inability to acquire food in socially acceptable ways (FAO, 2023). According to the U.S. Department of Agriculture, Economic Research Service, food insecurity is

a household-level socio-economic condition of limited or uncertain access to adequate food (USDA, 2022).

Food insecurity has been identified as a contextual barrier to the achievement of UNAIDS 90-90-90 targets (Ojo et al., 2022) . In SSA, food insecurity is pervasive, and close to two-thirds (66%) of the population experienced moderate to severe food insecurity in the year 2020 (Wang et al., 2022). Within that population, PWH had a higher prevalence of food insecurity compared to the rest of the population. This is contradictory to the finding by Onyenakie et al. (2022), however, who did a cohort study on the prevalence and predictors of food insecurity among PWH and those living without HIV in Africa, that the prevalence of food insecurity was comparable between PWH and those without (Onyenakie et al., 2022).

Food insecurity has been shown to interfere with treatment effectiveness among PWH thus increasing their odds of sub-optimal viral suppression (Aibibula et al., 2017; Cohen et al., 2022; The Lancet HIV, 2020; Weiser et al., 2017). Food insecurity increases risk of HIV acquisition (Weiser et al., 2017), and food-insecure PWH have worse adherence to ART; contributing to poor HIV treatment outcomes and increased morbidity and mortality (Weiser et al., 2017). Kenya fell short of achieving the 2020 90-90-90 targets; and meta-analyses have shown that the lower odds of achieving complete suppression of HIV among PWH experiencing food insecurity is 29% (Aibibula et al., 2017). Evidence from the Shamba Maisha cluster randomized trial in western Kenya further demonstrates that PWH experience high levels of food insecurity and structural vulnerability, including poverty and livelihood instability, which are closely linked to HIV-related health risks (Cohen et al., 2022). In this study, food insecurity was shown to operate through nutritional, mental health, and behavioral pathways that can undermine treatment adherence and overall health outcomes among PWH. In addition, while the Shamba Maisha intervention improved food security, mental health, and social support, these structural constraints persisted as critical determinants of health even in the context of widespread ART access (Cohen et al., 2022).

In their syndemic-based scoping review of HIV, TB and food insecurity in Africa, Ojo et al., (2022) found evidence of intersectionality between food insecurity, HIV & AIDS, other co-infections, limited resources, socio-economic inequities and weak health systems. The review singled out economic barriers like unemployment as a cause of food insecurity and consequent barrier to successful HIV treatment outcomes. Of the 18 studies included in this review however, water

insecurity did not feature, despite the evidence shown by a number of studies that food insecurity not only co-occurs with but is also driven by water insecurity (Bethancourt et al., 2023; Boateng et al., 2022; Miller et al., 2021a).

Building on the evidence that food insecurity and household water insecurity are both prevalent and often co-occurring public health challenges (Bethancourt et al., 2023; Boateng et al., 2022; Frongillo, 2023), both are conceptualized as forms of resource insecurity, capturing distinct yet interconnected dimensions of material deprivation (Maxfield, 2020). While food insecurity has been extensively studied and operationalized, water insecurity encompasses a broader range of constraints extending beyond consumption to include hygiene, household functioning, and livelihoods. Thus, though related, these constructs may operate through overlapping yet distinct pathways to determine HIV treatment outcomes.

While these findings have advanced the understanding of food insecurity as a structural driver of HIV outcomes, far less attention has been given to water insecurity, which may operate through similar and overlapping pathways. However, unlike food insecurity that involves challenges related to availability, access, utilization, and stability, water insecurity is uniquely characterized by risks arising from both extremes: scarcity and excess availability, thereby introducing additional and more complex constraints on daily functioning and health. Given its central role in hydration, hygiene, food production and preparation, and treatment adherence, water insecurity may therefore exert distinct and potentially more immediate and multi-dimensional effects on the ability of PWH to sustain uninterrupted engagement in HIV care. This points to the need to examine how water insecurity shapes HIV treatment engagement and outcomes, particularly through the lived experiences of those affected.

The synergistic interactions between water insecurity and food insecurity can mask the important but independent role of water insecurity in health challenges associated with HIV such as water-related illnesses and dehydration. Furthermore, examining the role of water insecurity as an independent predictor is likely to provide valuable insights for policy interventions, in addition to allowing a more nuanced understanding of its impact within the specific regional context that is still burdened by HIV. Because of this co-occurrence with water insecurity, and the similarities in impact on HIV health, it may be necessary to measure and adjust for food insecurity when

evaluating the independent, but not the total association of water insecurity with HIV treatment outcomes.

2.6 Physical water-related illnesses

Access to safe and adequate water is essential for promoting hygiene practices, which serve as a crucial preventive measure against not only diarrheal diseases but also acute respiratory infections and various neglected tropical diseases (WHO, 2022b). Water insecurity is strongly interconnected with the prevalence of water related diseases, which can lead to severe health consequences. According to the WHO and UNICEF (2022), water-related diseases can be classified into 4 major categories (WHO & UNICEF, 2022), as follows:

- Water-borne diseases, which are infections spread through contaminated drinking water
- Water-washed diseases, which include diseases due to the lack of proper sanitation and hygiene
- Water-based diseases, which are infections transmitted through an aquatic invertebrate organism
- Water-related vector-borne diseases, which include diseases transmitted by insect vectors that depend on water for their propagation.

The contamination of water sources, along with poor sanitation and inadequate hygiene practices, significantly contribute to the transmission of water-related illnesses like cholera, and waterborne illnesses are among the most persistent economic and biological threats to communities (Shayo et al., 2023).

Physical waterborne illnesses pose serious health risks on a global scale. Access to safe drinking water, sanitation, and hygiene practices play a pivotal role in preventing diarrheal illnesses, which are a frequent occurrence among PWH. Cholera, caused by the bacterium Vibrio cholerae, spreads through contaminated water and results in severe diarrhea and dehydration (Shayo et al., 2023). Dysentery, caused by bacterial or parasitic infections through water, leads to issues such as bloody diarrhea. Typhoid fever, caused by the waterborne agent Salmonella typhi, manifests as a high fever and abdominal pain. Giardiasis, caused by the parasite Giardia lamblia, leads to diarrhea and abdominal cramps and spreads through contaminated water. Hepatitis A, a liver virus, exhibits

symptoms like jaundice and flu-like signs, and it also spreads through contaminated water (Shayo et al., 2023).

Cryptosporidiosis, an infection caused by cryptosporidium parasite that is spread mainly via the fecal-oral route, and which has a worldwide distribution, is more prevalent in lower income regions where access to potable water and improved sanitation are limited. Among immunocompetent individuals, it tends to cause self-limiting diarrhea or may even show no symptoms at all. Among PWH with lowered immunity however, cryptosporidiosis can progress to chronic diarrhea, leading to a higher burden of disease and even death if not controlled in a timely manner (Mohebali et al., 2020).

To mitigate these water-related health risks and safeguard the well-being of PWH, access to safe water is of utmost importance. By ensuring access to clean and uncontaminated water sources, communities can significantly reduce the incidence of waterborne diseases and protect public health.

Apart from waterborne diseases, there are also water based and water related vector-borne diseases, which are diseases caused by infection from pathogens transmitted by vectors that breed in water. Such diseases include schistosomiasis, caused by consumption of fresh water contaminated with parasitic flatworms, and malaria, an important cause of death due to infection by plasmodia following the bite of mosquitoes (WHO & UNICEF, 2022). Malaria is especially important because it is endemic in the study region, and PWH require more safeguards against it to prevent infection.

2.7 Mental health and well-being

Water insecurity has been found to be positively associated with poor mental health status and increased odds of depression, which, in turn, is associated with ART non-adherence and sub-optimal viral suppression among PWH (Miller et al., 2021a). Emerging evidence further suggests that mental health may represent a critical, yet underexamined pathway linking water insecurity to HIV outcomes, especially due to extreme weather phenomena like floods (Beyeler et al., 2023; Lieber et al., 2021). Consistent with this, mental health symptoms, particularly depression, have been shown to adversely affect HIV care outcomes, including poorer retention in care, thus increasing the risk of treatment failure (Lopez et al., 2023). Apart from the direct consumption of

water via food and drinking, water serves other vital social and economic functions beyond consumption, including sanitation, household tasks, bathing, and livelihood activities (Miller et al., 2021a). Accordingly, water-related challenges that impede people's ability to meet their individual and social needs have been found to invariably cause mental anguish to those affected; in the form of worry, stress, anxiety, and shame (Wutich, 2020).

When multiple epidemics co-occur within a population, a syndemic results from their combined and multiplicative impacts. Studies in Lesotho, Kenya, and Haiti have shown an association between water insecurity and psychosocial distress (Boateng et al., 2022; Brewis et al., 2019; Workman & Ureksoy, 2017). Workman & Ureksoy (2017) investigated the psycho-emotional impacts of water insecurity and household illness as well as food insecurity on men and women domiciled in three low-land Lesotho districts using a mixed-method research approach involving quantitative assessment and qualitative interviews, including a water insecurity scale, household illness, demographics, the Hopkins Symptoms Checklist-2, and the Household Food Insecurity Access Scale. The authors found that water insecurity is a crucial syndemic factor in Lesotho, along with food insecurity, shifting household demographics brought on by the HIV/AIDS epidemic, and evidence of increased anxiety and sadness.

In a study conducted in Kenya among expectant mothers living with HIV, water insecurity was found to be associated with psychosocial distress; whereby women expressed frustrations and stress linked to fetching water. Such frustrations, which included contemplating possible sources of water, how and when to fetch it, as well as waiting time, sometimes came with additional risks of injury and intimate partner violence (Collins et al., 2019). Miller et al., (2021) examined the relationships between water insecurity and food insecurity and their association with mental and physical health among PWH in western Kenya using a cluster-randomized controlled experiment. From the findings of that study, the lack of access to clean water was linked to higher probabilities of depression and lower summary scores on mental health (Miller et al., 2021a).

Overall, these studies suggest that mental health is not only an outcome of water insecurity, but also a plausible intermediary mechanism through which water-related stressors may translate into compromised HIV treatment behaviors and outcomes.

2.8 A synthesis of plausible mechanisms linking water insecurity and HIV treatment outcomes

Boateng et al., (2022) investigated the intricate connections between water insecurity, mental health, food insecurity, and HIV on depressive symptomatology amongst women in Kenya with mixed HIV status, using the syndemic theory. Framed within a syndemic perspective, the study looked at how co-occurring resource insecurities and HIV infection interact to amplify psychological vulnerability. Boateng et al. (2022) established that water insecurity has a predominately unidirectional and predictive relationship with food insecurity; there is, however, no evidence of a reverse causal relationship between food insecurity and water insecurity. This directional relationship is important, as it suggests that water insecurity may function as an upstream driver of food insecurity. That distinction has important analytical implications for the present study, especially in determining whether to treat food insecurity as a confounder or as an intermediate variable in the relationship between water insecurity and HIV treatment outcomes.

Since PWH require more water than non-HIV individuals do, water insecurity could have greater detrimental effects on them (Krumdieck et al., 2016). In a cohort of more than 320 pregnant women from Kenya with mixed HIV status, 77.7% reported having experienced water insecurity at least once in the month before, and it was linked to poor economic, nutritional, medical, and psychological consequences. The biological implications of water insecurity extend beyond psychosocial stress. PWH are more vulnerable to water-related opportunistic illnesses, and drinking unclean water is riskier for them. In turn, diarrheal disorders can cause dehydration, lowered immune function, poor intestinal absorption of medication, and an increase in viral load. This creates a plausible biological pathway linking water insecurity and HIV treatment outcomes.

Although Krumdieck et al., (2016) recommended examining CD4 counts and viral load by water insecurity status, their study did not address the impact of excessive water availability due to flooding, a critical but often overlooked dimension of water insecurity, on the health and well-being of PWH. This omission highlights a gap in understanding the full spectrum of water insecurity, particularly in contexts characterized by hydrological variability. Collins et al., (2019) carried out an exploratory study with 40 postpartum and pregnant women in Kenya living in an area with high HIV prevalence. The authors (Collins et al., 2019) examined how women acquired, prioritized, and used water. The findings revealed that water insecurity during pregnancy and

postpartum periods was especially severe and had far-reaching implications. Notably, HIV-positive women reported prioritizing water acquisition over medication and clinic attendance. This prioritization reflects constrained agency and competing survival demands, illustrating a direct behavioral mechanism through which water insecurity may disrupt treatment engagement.

The studies above suggest that water insecurity may affect HIV treatment outcomes through interrelated physical, psychosocial, behavioral, and biological processes. However, existing evidence is largely limited to documenting associations between water insecurity and HIV-related outcomes, without explicitly elucidating the underlying pathways, which leaves a gap in knowledge and understanding about mechanisms of association. Additionally, the relative contribution and interaction of these processes remain insufficiently characterized. The available evidence on association also remains largely cross-sectional, often only focuses on single or isolated HIV treatment outcomes, for example, ART adherence alone; and rarely consider s HIV treatment outcomes in their totality. Furthermore, the evidence is often limited to specific populations such as pregnant women or PWH enrolled in studies designed to investigate other exposures where water insecurity was only measured as a covariate.

Few studies have integrated mechanisms of association within a unified socio-ecologic framework or empirically considered both scarcity and excess water conditions when investigating water insecurity among PWH. Collectively, this body of evidence remains conceptually and empirically fragmented, with limited integration across populations of PWH, contexts, exposures, mechanisms, and outcomes. This fragmentation signals the need for theoretically grounded investigation into how multidimensional water insecurity may disrupt HIV treatment continuity and outcomes among adults on ART.

Methodological Gaps in the Literature on Water Insecurity and HIV Outcomes

Although emerging evidence suggests associations between water insecurity and sub-optimal viral suppression, opportunistic infections, and poor adherence, several methodological limitations constrain interpretation of these findings.

First, much of the literature relies on cross-sectional study designs, limiting causal inference and obscuring temporal sequencing between water insecurity and treatment outcomes. It remains unclear whether water insecurity precedes virologic failure, whether deteriorating health status increases vulnerability to water insecurity, or whether bidirectional relationships exist. Second,

studies often operationalize water insecurity as a single composite exposure without disaggregating dimensions such as availability, access, and quality. This limits the understanding of which specific aspects of water insecurity are most salient for HIV treatment continuity. Third, few studies also integrate objective clinical markers, such as viral load or CD4 count, alongside multidimensional water insecurity assessments. Mediation pathways also remain underexplored. While psychosocial distress, food insecurity, and physical morbidity are hypothesized mechanisms linking water insecurity to HIV outcomes, few studies formally examine these intermediary processes within integrated analytical models. Finally, flooding and excess water availability are rarely incorporated into analyses of HIV outcomes, despite their potential to disrupt infrastructure, displace households, and interrupt care. These limitations underscore the need for multidimensional, theoretically grounded investigations that distinguish drivers from dimensions, incorporate objective clinical outcomes, and examine psychosocial and structural mediators. Addressing these gaps is essential to clarify the independent and interacting effects of water insecurity on HIV treatment outcomes.

2.9 Summary of concepts

The literature reviewed in this chapter shows that water insecurity is not a singular condition but a structurally produced, multidimensional phenomenon shaped by interacting socio-ecologic forces. Environmental stressors, infrastructural constraints, socio-economic inequalities, and governance contexts operate across structural, community, interpersonal, and individual levels to influence vulnerability to unstable water systems. These upstream forces manifest proximally through disruptions in water availability, access, and quality, which together define the measurable dimensions of water insecurity.

Beyond material instability, water insecurity is experienced as a lived condition that reshapes daily routines, resource allocation, and health-related decision-making. Interpreted through the Capability Approach, these experiences reflect constraints on individuals' substantive freedoms to maintain health, dignity, and consistent engagement in care. Among PWH, such constraints may intersect with treatment demands, psychosocial stressors, and competing survival priorities in ways that threaten treatment continuity.

Although prior research has examined determinants of water insecurity, explored psychosocial implications, and reported associations with HIV-related outcomes, the evidence remains conceptually fragmented. Determinant studies often lack multilevel integration; experiential studies rarely anchor findings in explicit theoretical frameworks; and quantitative analyses of water insecurity and HIV outcomes are predominantly cross-sectional, seldom disaggregate dimensions, and infrequently situate associations within a unified socio-ecologic structure.

In relation to **Objective 1**, there remains a need for empirically grounded, multilevel examination of socio-ecologic drivers among adults on ART. For **Objective 2**, limited research has systematically explored the lived experience of water insecurity among adults on ART using a phenomenological approach informed by capability theory. Concerning **Objective 3**, while associations between water insecurity and adverse HIV outcomes have been documented, few studies have tested these associations beyond cross-sectional designs.

Collectively, these gaps point to the necessity of an integrated conceptual model that links socio-ecologic drivers, multidimensional water insecurity, and HIV treatment outcomes. The conceptual framework presented in the next section synthesizes these elements and provides the structural foundation for addressing the study objectives.

2.10 Conceptual Framework

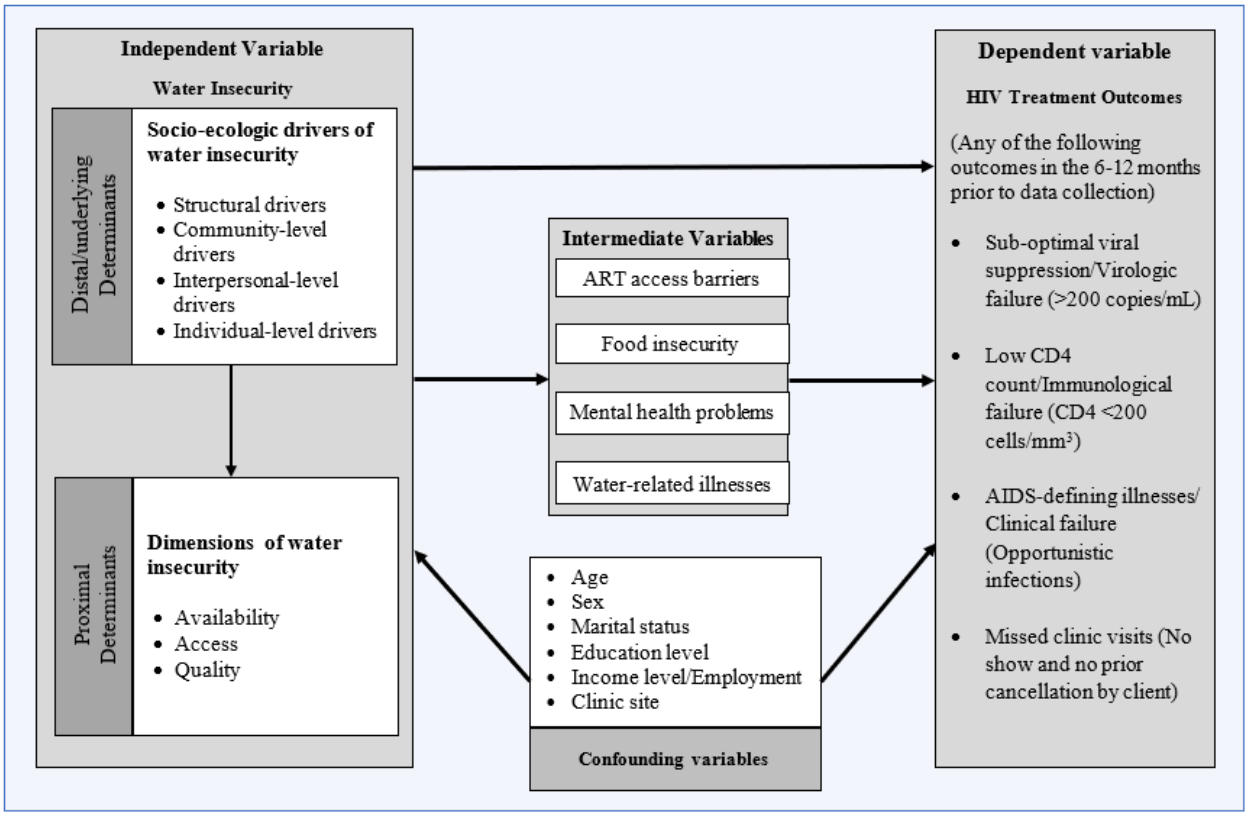


Figure 2.2: Study conceptual framework

Independent/exposure variable: Water insecurity

The primary independent variable for this study was water insecurity. However, it was operationalized differently across study objectives in accordance with the analytic aims of each phase. For the first specific objective, water insecurity was the outcome variable, with socio-ecological drivers and dimensions examined as predictors in a bid to characterize its determinants among adults on ART in Kisumu County. For the second and third specific objectives, water insecurity was the key independent variable, examined as the phenomenon/exposure in relation to HIV treatment outcomes. Therefore, the use of water insecurity as both an outcome and an exposure does not imply bidirectionality within a single analytic model, but rather reflects its distinct conceptual role across sequential study objectives, so that it is an outcome when the objective is to characterize its determinants, and as an exposure when the goal is to examine its downstream HIV health consequences. Drawing from the SEM, it is conceptualized that distal drivers of water insecurity lead to the proximal dimensions of water insecurity (availability, access,

and quality) that are experienced by households. The downward facing arrows in the independent variable box illustrate these relationships.

Intermediate variables

Water insecurity gives rise to intermediate challenges like ART access and adherence barriers, food insecurity, mental health problems, and water-related illnesses which in turn have consequences for HIV treatment outcomes. These relationships demonstrate the indirect effect of water insecurity on HIV treatment outcomes as shown by the arrows leading to and from the intermediate variables.

Dependent variable: HIV treatment outcomes

The dependent variable for this study was HIV treatment outcomes, operationalized as a composite outcome. In this study, the observation of any of the following constituent outcomes in adults on ART constituted an observation of the dependent variable: unsuppressed viral load (≥200 copies/mL) as at the most recent test, that is, HIV viral load starting from 200copies/mL and above, most recent CD4 count <200 cells/mm^3, AIDS-defining illnesses/opportunistic infections in the 12 months prior to the study, and missed clinic visits within the last 12 months.

The total effect of water insecurity on HIV treatment outcomes is represented by the top straight arrow from the independent to dependent variable.

Confounding variables

The potential confounding variables that are known to be associated with both the independent variable (water insecurity) and the dependent variable (HIV Health outcomes) have arrows leading to both the independent and dependent variables. The confounders were selected in advance and include age, sex, marital status, education level, income, employment status, and clinic site. They are not in the causal pathway between water insecurity and HIV health outcomes and were identified from literature, and those to be adjusted were determined using Directed Acyclic Graphs (DAGs). Apart from being analyzed as a confounder, sex was also examined as an effect modifier to assess whether the association between water insecurity and HIV treatment outcomes differed between adult men and women on ART.

CHAPTER THREE: MATERIALS AND METHODS

This section provides a detailed methodology used to address the research objectives and answer the research questions and hypotheses. It includes detailed descriptions of the study area, study design including the philosophical anchoring/research paradigm, the study population, sampling design, data collection materials and methods, quality assurance, data management and analysis, and the ethical considerations that underpinned the research and provided safeguards to protect participants from harm due to their participation in the research.

Parts of the methods described in this chapter informed subsequent peer-reviewed publications arising from this doctoral research. Where applicable, sections of this chapter, especially regarding specific objective one, may therefore show similarity to published work derived from the same study. These publications are based on the original work conducted for this thesis.

In this study, sex refers to the biological classification of participants as male or female, as recorded during enrolment and used in all quantitative analyses. Gender refers to the socially constructed roles, norms, and relations that influence experiences of water insecurity and HIV care, and was explored qualitatively through participants' narratives. Accordingly, quantitative analyses examined effect modification by sex, while qualitative findings considered the influence of gendered social roles and expectations where relevant.

3.1 Study area

Kisumu County is situated between longitudes 33^0 20'East and 35^0 20'East, and latitudes 0^0 20'South and 0^0 50' South. The County has an area of about 567 Km^2 under water and 2,086 Km^2 land area. It sits at an elevation of 1,131m above sea level. It is bordered by 5 Counties: Siaya to the West, Vihiga to the North, Nandi to the Northeast, Kericho to the East, Homa Bay to the South, and most of the western part lies along the shores of Lake Victoria (County Government of Kisumu, 2023). Kisumu County has a population of about 1.156 million people and a population density of 550 persons per Km^2 (KNBS, 2019). The County has 7 Sub-Counties including Kisumu West, Kisumu Central, Kisumu East, Seme, Muhoroni, Nyando, and Nyakach.

Kisumu County is one of the 4 counties bordering Lake Victoria. Similar to the other three counties of Homa Bay, Siaya and Migori, it has consistently recorded one of the highest prevalence of HIV. It was selected for this study because it has been reported as one of the counties in Kenya with the highest number of new HIV infections and AIDS-related deaths and is currently leading in HIV

prevalence nationwide (NSDCC, 2024). Despite its proximity to the lake, water availability, access and quality vary across the region. The County experiences both very dry conditions and bi-annual flooding, this latter attributed to Rivers Nyando and Sondu-Miriu that periodically burst their banks during the rainy seasons. Additionally, its location on the Winam Gulf causes back-flow flooding in adjacent areas. The back-flow is attributed to increased water levels in the lake due increased precipitation in the Highlands caused by a changing climate. Kisumu County also has more industries compared the other Lake region counties, and some of these industries discharge effluent into the surrounding water bodies, causing chemical contamination of water sources.

Considering the population of Kenya, Kisumu is one of the larger fast-growing cities, has a water insecurity problem and a high HIV prevalence (11.7%) – almost 4 times the national prevalence (3.1%) compared to for example, only 2.3% in Kilifi County (NSDCC, 2024) which is an ASAL region with severe water scarcity. There is clearly a much bigger problem in Kisumu County with regards to the outcome of interest which is HIV treatment outcomes. With the scientific requirement for transferability of findings and the research requirement to generate evidence that can inform and lead to policy implementation, Kisumu County was a better 'model' region for generating evidence on overall water insecurity that would be useful for quick translation into interventions on water security and infrastructure development.

3.1.2 Study setting

Out of the seven Sub-Counties, the study was conducted in three: Nyando, Nyakach, and Seme Sub-Counties. Three Sub-counties of Kisumu Central, Kisumu East, and Kisumu West were deliberately left out because they are urban or peri-urban, have piped water supply, and most adults are employed and difficult to find at home to enrol for household interviews. The final three were randomly selected from the four rural and semi-rural Sub-Counties within Kisumu County, with remaining one, Muhoroni Sub-county, being used for the pre-test. The participating study sites were Ahero, Nyakach, and Kombewa County hospitals from where participants were identified within each Sub-County respectively. These facilities were selected because they have comprehensive care centers (CCCs), HIV testing services (HTS), and serve large volumes of clients.

3.2 Target population

The study targeted as adults on ART living around the Lake Victoria region, Kenya. The age group from 15-64 years was selected to align with Kenya's specification of adult HIV population (NSDCC, 2024)

3.2.1 Study population

The study population comprised PWH aged 15 – 64 years on ART in Kisumu County (~122,000 PWH) estimated from the Kisumu County HMIS, 2024). The 15-64 years group was appropriate because of its epidemiological relevance, since this range spans a significant portion of the population with a high HIV prevalence, and in which individuals are more likely to engage in sexual activity and potentially be at risk of HIV acquisition and transmission.

3.2.2 Accessible/Sample population

The accessible population comprised adults (15-64 years) on ART from Ahero (~3569), Nyakach (~1904), and Kombewa (~3488) County hospitals in Nyando, Nyakach and Seme Sub-Counties respectively. Total accessible population from which the sample was drawn was 8,961.

Inclusion criteria

To be enrolled in the study, participants had to be:

i. Adults on ART in participating public health facility (Ahero, Kombewa and Nyakach).
ii. Aged 15–64 years at last birthday
iii. Resident of Kisumu County.
iv. Provided written informed consent to participate voluntarily

Exclusion criteria

The study excluded:

i. Eligible participants who could not be reached after three attempts to recruit them.
ii. Eligible participants with severe cognitive and/functional impairment.

3.3 Study design

This study employed an **integrated multiphase mixed methods design,** comprising multiple epidemiologic study designs that were implemented to address distinct but related research

objectives. The mixed-methods approach was informed by **pragmatism** as the guiding research paradigm for the study. A pragmatist research paradigm, according to Allemang et al. (2021), emphasizes using the most effective methods to investigate and solve complex, real-world problems. Pragmatism supports a problem-centred approach that allows researchers to draw from multiple forms of data and knowledge to generate practical answers to research questions (Allemang et al., 2022). By focusing on the practical research problem rather than a singular philosophical tradition, this paradigm provides the theoretical justification for a **mixed-methods design**. Ultimately, utilizing a pragmatic framework ensures that the methodology is problem-centred, employing a multi-pronged strategy to generate actionable evidence for improving patient care. In the context of water insecurity among adults on ART, this research paradigm provided a suitable foundation for employing a research design that combined quantitative and qualitative approaches.

Specifically, the design integrated cross-sectional, laboratory-based, qualitative, and case-control approaches. Since water insecurity has not been researched much in the context of PWH, it was necessary to first, establish its prevalence, drivers/predictors, and manifestations; second, explore how the phenomenon is experienced by adults on ART; and third, test whether there is an association between water insecurity and HIV treatment outcomes. Therefore, objective one was addressed using a **cross-sectional survey** with a nested **laboratory-based** water quality testing, objective two was addressed through a **qualitative exploratory study**, while objective three was addressed using a **case-control design.**

Quantitative and qualitative data were collected and analyzed as complementary components rather than in a strictly sequential explanatory or exploratory manner. Instead, **a convergent mixed-methods logic** was applied across phases, with qualitative participants drawn from the two quantitative components and integration occurring during interpretation. This design allowed findings from different phases and data types to be compared, corroborated, and contextualized, while accommodating the complexity of examining water insecurity and HIV health.

To provide context, multiphase designs are commonly used in the health sciences to link multiple studies conducted over time around a common research purpose, and they commonly involve convergent and sequential elements (Creswell & Poth, 2016). In this study, the multiphase design applying a convergent logic was thus considered most appropriate and adapted for the current

research. The multiphase structure allowed the use of different study designs to address distinct research objectives, while convergence was applied analytically through the comparison and integration of quantitative and qualitative findings. Integration and interpretation of the results were done in chapters four and five under results and discussion sections respectively. Since the use of quantitative and qualitative methods occurred logistically, not inferentially, a sequential mixed-methods design was considered inappropriate.

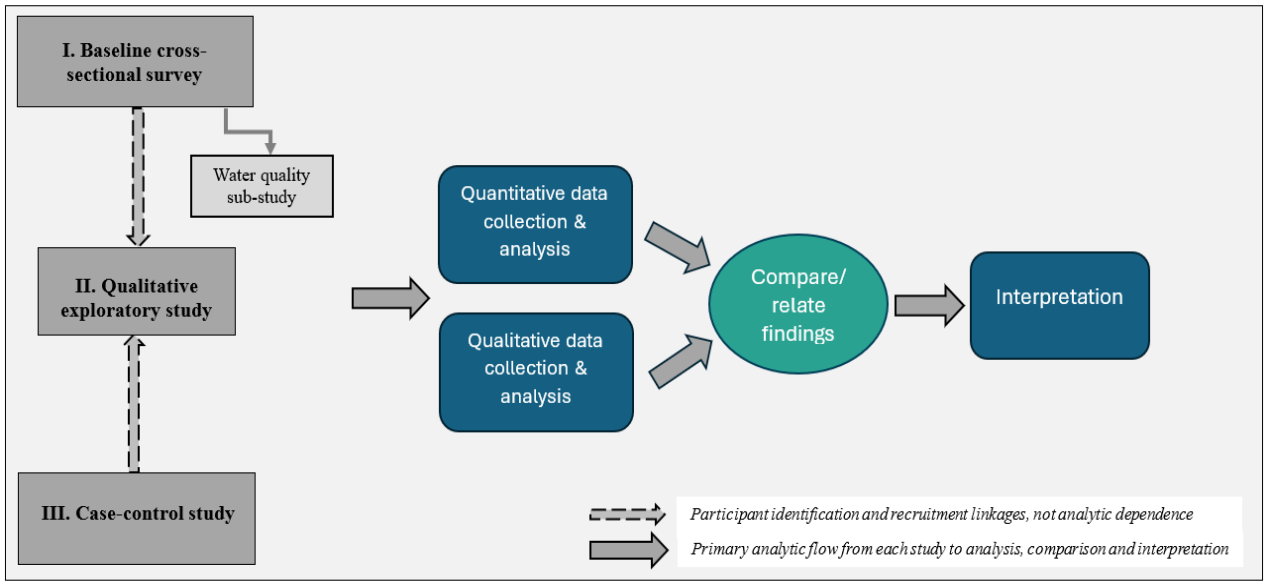


Figure 3.1: Study design

3.3.1 Phase I: Baseline cross-sectional survey

The baseline cross-sectional study was used to answer the first research question on the socio-ecological drivers and the dimensions of water insecurity among adults on ART in Kisumu County. The baseline study was done to establish the prevalence of household water insecurity in the study sample, and to characterize the distal causes (drivers) and proximal manifestations (dimensions) of water insecurity. As an important dimension of water insecurity, a small, nested laboratory based sub-study was conducted to characterize the microbiological and physicochemical quality of selected water sources commonly used by participants. Water quality was determined by collecting and testing samples of water drawn from mostly communal water sources in the participating sites using laboratory techniques. Apart from environmental sampling and testing of water quality, the baseline study was conducted in participants' households. The household survey

informed the purposive identification and recruitment of water insecure participants for the second main phase - the qualitative study.

3.3.2 Phase II: Qualitative exploratory study

This study was used to answer the second research question which sought to explore the lived experience and pathways through which water insecurity could impede successful HIV treatment outcomes among adults on ART in Kisumu. Lived experience methods are recommended when study's objective is deep and contextual exploration of a phenomenon (Prosek & Gibson, 2021).

The qualitative study was designed as an exploratory study informed by phenomenology. Phenomenology seeks to grasp the essence of a phenomenon, such as water insecurity, as individuals experience it. It explores participants' lived experiences to uncover the underlying structures and meanings inherent in those experiences. Criterion sampling and stratified purposive sampling are commonly used in phenomenology, where participants are selected based on predefined criteria (Moser & Korstjens, 2018). In phenomenological research, in-depth interviews or focus groups are commonly employed to engage with participants who have encountered the phenomenon in question. For this objective, data were collected using in-depth interviews (IDIs) and focus group discussions (FGDs); which are appropriate for uncovering detailed accounts of lived experiences and shared patterns of meaning. Participants were recruited and interviewed in a staggered manner, with rapid appraisal of interview content to determine data richness and thematic saturation.

3.3.3 Phase III: Case-Control Study

The third phase of the study was a case-control study. It was used to test the hypothesis that there is no association between water insecurity and HIV treatment outcomes among adults on ART in Kisumu County, and by extension, that the association is not modified by sex. In the case-control study, participants were identified from the Ministry of Health (MoH) electronic medical records (EMR) at the participating study sites, based on the case definition of the study (Section 3.3.1). From the list of outcomes making up the composite of HIV treatment outcomes, the primary classification outcome was the most recent viral load (VL), because, based on existing guidelines, sub-optimal viral suppression is recommended as most predictive of treatment failure (Panel on Antiretroviral Guidelines for Adults and Adolescents, 2025). For that reason, cases were initially

identified based on sub-optimal viral suppression, defined as a viral load ≥200 copies/mL, and controls were adults on ART with VL<200 copies/mL (MOH (NASCOP), 2022).

After classification based of viral load, potential cases and controls were stratified by sex, resulting in four groups. A total of 210 cases (19 more than the sample size to allow for unreachable cases) were then randomly selected proportionately across these groups. Because age, sex, and time on ART were available for all participants, three times the required number of controls were randomly selected to create a sufficiently large pool for matching.

After initial classification and stratification, cases were matched to controls 1:1 on age, sex, and time since ART initiation. While some cases had exact matches, others could not be matched strictly on age and time on ART using the available controls. For these cases, a matching range of ±2 years for both age and time on ART was applied.

Following the matching process, selected participants were contacted and appointments were arranged for consent and interview administration. Some selected cases could not be reached for consent; consequently, their matched controls were not contacted.

After providing informed consent, a screening questionnaire was administered to all participants to ascertain their outcome status. Participants who were initially classified as controls were reclassified as cases if they met any of the following additional criteria: documented low most recent CD4 count (<200 cells/mm^3), presence of or treatment for opportunistic infections despite being on effective treatment, or missed clinic visits in the 12 months prior to the date of interview.

None of the initial cases was reclassified as a control. Figure 3.2 below is a flowchart illustrating the case-control study design.

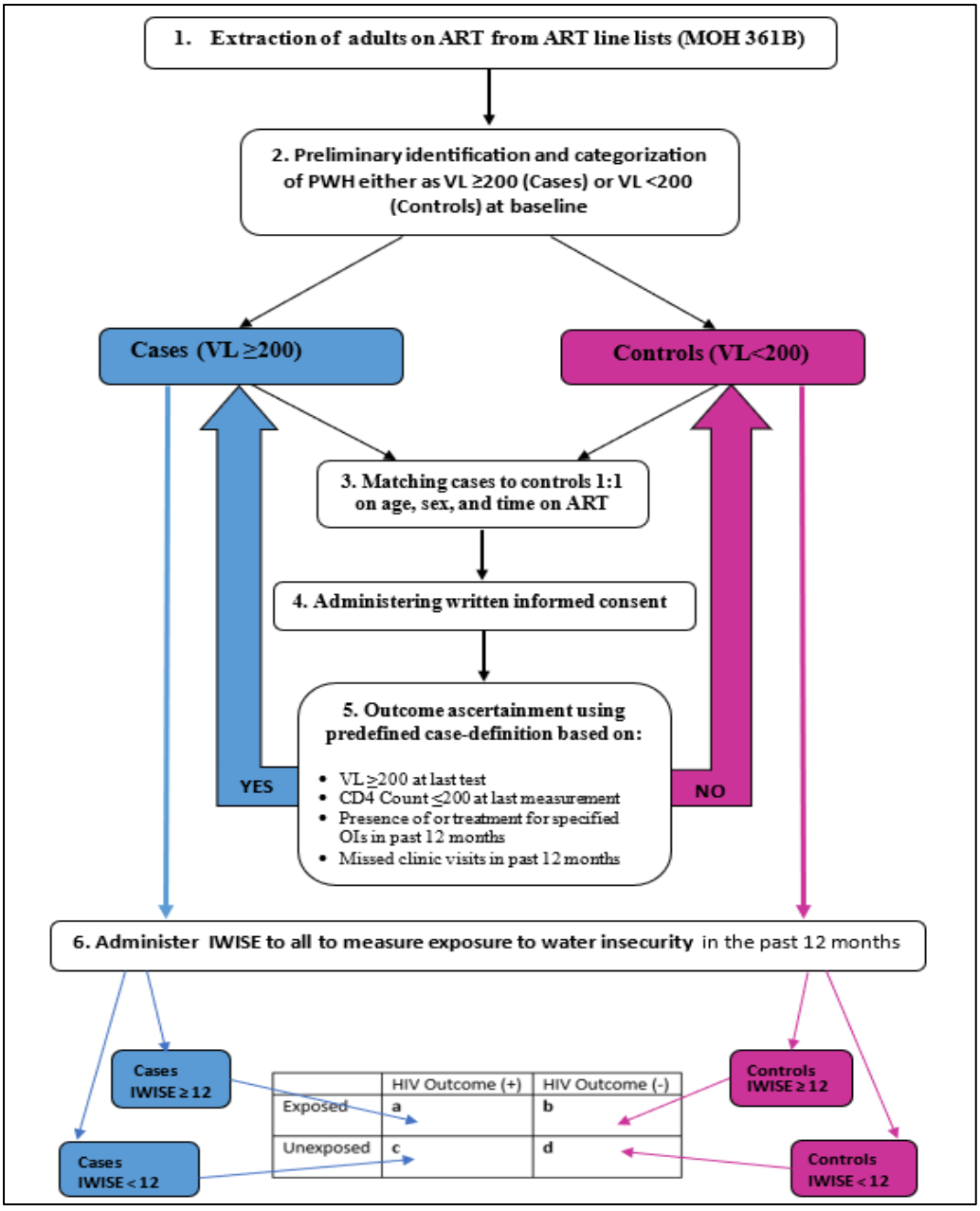


Figure 3.2: Flowchart of Phase III – case-control study

3.3.4 Design rationale and justification

The choice of a phased convergent mixed-methods approach that integrated quantitative epidemiologic data with nested environmental water quality testing, and qualitative experiential data was to allow a comprehensive examination of water insecurity and its implications for HIV health in Kisumu County. In line with pragmatism, this design was informed by the fact that no single study design could adequately address the study objectives, requiring complementary

approaches to estimate prevalence and characterize determinants, explore lived experiences, assess water quality, and quantify the association between water insecurity and HIV treatment outcomes.

Within the first phase, quantitative data were used to characterize the burden (prevalence) and determinants of water insecurity using a cross-sectional design (also referred to as prevalence studies). Annexed to the prevalence study, environmental testing of commonly used water sources provided biophysical evidence of water quality as one of the dimensions of water insecurity, enabling assessment of microbiological and physicochemical safety. Qualitative data captured the lived experiences of people living with HIV, elucidating how challenges related to water availability, access, and safety are navigated in daily life and how they may interfere with HIV care. In the third phase, a case-control design was used to derive a measure of association between water insecurity and HIV treatment outcomes; first, because it was not expected that there would be large numbers of observations of the outcome, thus ruling out a cohort study. Second, because a case-control study is methodologically superior to a cross-sectional study, and has an inherent time aspect, making it comparable to a cohort study. Triangulating findings across epidemiological, experiential, and biophysical dimensions strengthened the validity of the study by situating water insecurity within its structural context, grounding it in participant experiences, and corroborating perceived health risks with objective environmental data.

3.4 Sampling design

The study employed both probability and non-probability sampling methods. These included systematic, stratified random sampling, and purposive sampling as appropriate for each specific objective.

3.4.1 Sample size determination

3.4.1.1 Phase I: Baseline Cross-sectional study sample size

The sample size for **objective one** was calculated using the Rodríguez del Águila and González-Ramírez (2014) formula because it is specifically designed for estimating sample size in cross-sectional studies where the primary objective is to estimate the prevalence of a population characteristic with a specified level of precision. (Rodríguez del Águila & González-Ramírez, 2014) Unlike more generic formulae, it explicitly incorporates the desired confidence level,

precision, and expected prevalence, making it appropriate for prevalence estimation in epidemiological cross-sectional studies. Based on that formula: $n = \frac{t_\alpha^2 * p * q * N}{(N-1) * e^2 + t_\alpha^2 * p * q}$

Where: n = sample size

N = Size of the population from which the sample is drawn. In this study, N = 8961

t_α = Statistic for a 95% level of confidence which = 1.96

p = Expected percentage of the response variable = 0.6 (estimated from Okwara et al., 2024)

q = 1-p = 1- 0.6 = 0.4

e = 0.05

According to a recent study, the prevalence of water access in Kisumu County was about 42% (Okwara et al., 2024). For this study, the difference in water access was used as a proxy for the prevalence of water insecurity among adults on ART in Kisumu County. Therefore, based on a conservative estimate of about 60% prevalence of water insecurity in the study population, the sample size was computed using the formula above. Thus, substituting in the formula:

n = (1.96^2 x 0.6 x 0.4 x 8961) / ((8960*0.0025) + (1.96^2 x 0.6*0.4))

n = (3.8416 × 0.24 × 8961) / (22.4) + (3.8416 × 0.24)

n = **354**

Considering a dropout rate formula by Kang, (2021):

$n^d = \frac{N}{1-d}$ (Kang, 2021)

Where: n = Sample size before considering dropout

d = Expected drop-out rate, withdrawal, or nonresponse

n^d = Sample size accounting for drop-out rate;

And considering that in this study, some sampled adults on ART could be unreachable, decline, or be excluded because of advanced illness or cognitive/functional impairment, assuming an attrition rate of 20% (0.2). Therefore:

$n^d = \frac{354}{1-0.2}$

= 354/0.8 = 442.8

Total baseline study sample for objective 1 = **443** adults on ART

Baseline study sample size attained = **434 (98%).**

3.4.1.2 Phase II: Qualitative study sample size

This was a phenomenology-based exploratory study on the lived experience of water insecurity. Such a study usually makes use of small sample sizes, often 10 or less participants (Moser & Korstjens, 2018; Tirumalesh, 2019). Hays and Singh (2012) state that the sampling for lived experience should be purposive for the phenomenon of interest (Hays & Singh, 2012). According to Guetterman (2015), a sample of 15 is adequate for a phenomenological study (Guetterman, 2015). Creswell & Poth (2016) recommend between 5 and 25 interviews for a phenomenological study (Creswell & Poth, 2016). Prosek and Gibson (2021) however recommend that the sample size should be guided by the depth of experience the researchers seek to understand.

This study used stratified purposive sampling with maximum variation (based on age: 15-24; 25-34; 35-44; ≥45), socio-economic context, location, and sex to select water-insecure FGD and IDI participants (based on administration of the Water Insecurity Experiences Scales – HWISE and IWISE). The final sample size was based on saturation, which stopped at 21 IDIs and 7 FGDs with a total of 46 FGD participants.

3.4.1.3 Phase III: Case-Control study sample size estimation

To estimate a sample size with a 1:1 cases to controls ratio, the Charan & Biswas (2013) formula (Charan & Biswas, 2013) was employed.

$$n = \frac{2 \cdot p^* \cdot (1 - p^*) \cdot (Z_{1-\beta} + Z_{1-\alpha/2})^2}{(p_1 - p_0)^2}$$

Where:

p_1 = Expected proportion of exposure in cases

p_0 = Expected proportion of exposure in controls

$p^* = (p_1 + p_0)/2$ (Average proportion of exposed cases and controls)

$Z_{1-\beta} = 0.84$ (Standard normal deviate for $\beta = Z_\beta = 0.8416$ for 80% power)

$Z_{1-\alpha/2} = 1.96$ (Standard normal deviate for $\alpha = Z_\alpha = 1.9600$ for a 95% confidence level)

Continuing with the assumed prevalence of 60% water insecurity in adults on ART in Kisumu County, and a difference of 15% in exposure between cases and controls, then:

$P_0 = 60\% = 0.6$

$p_1 = 60\% + 15\%$

$p_1 = 75\% = 0.75$.

P* = (0.75 + 0.60) /2 = 0.675**.** Thus, for each group,

$n = [2 \times p^* \times (1 - p^*) \times (0.84 + 1.96)^2] / (p_1 - p_0)^2$

$n = [2 \times 0.675 \times (1 - 0.675) \times (0.84 + 1.96)^2] / (0.75 - 0.60)^2$

$n = [2 \times 0.675 \times 0.325 \times (2.80)^2] / (0.15)^2$

$n = [2 \times 0.219375 \times 7.84] / 0.0225$

$n = 3.4389 / 0.0225$

$n = 152.84$ = 153 per group

Total sample size for case-control study = 153 x 2 = 306

Correcting for nonresponse:

$n^d = \frac{306}{1-0.2}$ = 306/0.8

n = **382, (191 per group)**

Sample size attained = 356 (93%): 181 cases and 175 controls. Some controls were reclassified as cases because they met at least one of the other case definition criteria despite having VL<200.

3.4.2 Overall sampling procedure

- Random sampling of 3 different study locations (Nyando, Nyakach, & Seme Sub-Counties).
- The main Sub-County health facility, referred to as Ahero County hospital, Nyakach County Hospital, and Kombewa County hospital in each Sub-County respectively, was purposively selected as the participating study site.
- The study used MoH 362 (the HTS, lab, referral, and linkage register) and EMR to obtain lists of male and female adults (15-64 years) on care proportionately from each Sub-County health facility in those locations. These lists served as sampling frames, while individual adults on ART constituted the sampling units to be selected for inclusion in the study. The group of randomly selected sampling units as detailed below constituted the final study sample for the baseline and case-control studies.
- Participants for the qualitative study were identified using water insecurity status (HWISE/IWISE score ≥ 12) and were enrolled by age stratum to participate in IDIs and FGDs.

Phase I: Specific Objective 1 – To estimate the prevalence and characterize the socio-ecological drivers and dimensions of water insecurity.

i. After estimating a sample size of 443 for Objective one, systematic sampling with implicit stratification by sex was done to select a representative sample (n) from each sampling frame. The sampling frames consisted of 3,488 adults on ART from Kombewa, 3,569 from Ahero, and 1,904 from Nyakach county hospitals, giving a total population of 8,961 eligible participants.

   Proportional allocation was then used to determine the number of participants to be sampled from each site. Consequently, 39% of the sample was drawn from Kombewa, 40% from Ahero, and 21% from Nyakach, corresponding to sample sizes of approximately 172, 176, and 94 participants respectively, yielding the total sample size of 443.

   Within each facility, the sampling lists were first arranged by sex to achieve implicit stratification, and males and females were sampled proportionately according to their distribution in the sampling frame. The sampling interval (k) was calculated by dividing the total sampling frame by the desired sample size ($k = 8,961 / 443 \approx 20$). A random starting point between 1 and 20 was selected, after which every 20th individual on the list was selected until the allocated sample size for each facility was reached.

ii. The study used peer educators and mentor mothers to identify households to consent and enrol randomly selected participants in each study site. Because water insecurity was measured using the Household Water Insecurity Experiences Scale (HWISE), which captures household-level experiences, each selected participant served as a respondent representing their household. In cases where more than one selected individual belonged to the same household, only one respondent, in this case, the head of household or their representative was interviewed to avoid duplicate household measurements.

iii. Thirty-four (34) water samples were collected from household and communal water sources reported by participants for each study site to be analyzed for physical, pathogenic and chemical contamination in a laboratory. The samples were collected on different days, in different seasons, directly, using sterile one litre plastic containers. To safeguard the physical properties of the water, the samples were tightly closed and stored in a cooler box

with ice cubes between 0-6^{0}C immediately after collection and transported to the lab for analysis within 5 hours of collection.

Phase II: Specific objective 2 - To explore lived experience of WI and pathways to HIV outcomes.

For this study, participants were recruited based on water insecurity status (HWISE/IWISE ≥12) and were interviewed alongside preliminary content analysis. Recruitment and interviewing continued at each study site until saturation was attained. A total of 67 adults on ART (7 FGDs and 21 IDIs) participated in the qualitative interviews.

Table 3.1: Age-stratified breakdown of FGD & IDI participants by sex

AGE STRATA	**NYANDO**		**NYAKACH**		**SEME**		
FGDs (N = 7)	**M**	**F**	**M**	**F**	**M**	**F**	**Total**
15–24	0	0	0	0	0	0	0
25–34	0	1(n=7)	0	0	0	0	1
35–44	0	1(n=6)	0	1(n=8)	0	1(n=6)	3
45–64	0	0	1(n=6)	0	1(n=6)	1(n=7)	3
Total FGDs	**0**	**2 (n=13)**	**1(n=6)**	**1(n=8)**	**1(n=6)**	**2(n=13**	**7(N=46)**
IDIs (N = 21)	**M**	**F**	**M**	**F**	**M**	**F**	**Total**
15–24	1	0	0	1	1	1	4
25–34	0	2	0	0	0	0	2
35–44	0	3	1	1	1	1	7
45–64	1	2	2	1	1	1	8
Total IDIs	**2**	**7**	**3**	**3**	**3**	**3**	**21**

Phase III: Specific objective 3 - To measure the association of water insecurity and HIV treatment outcomes.

- This objective was met using case-control study with participants drawn from a fixed underlying cohort/study base of adults aged 15–64 years receiving ART at the three

participating health facilities in Kisumu County. Eligible participants were identified from the cohort of patients actively enrolled in HIV care during the study period.

- Cases were identified from the defined cohort using the predefined case definition for poor HIV treatment outcomes (see operational definitions). A list of all eligible cases meeting the first case definition criterion of VL≥200 copies/mL was drawn to form the case sampling frame.
- Potential participants in the same underlying cohort who did not meet the first criterion of case definition (VL≤200 copies/mL) formed the sampling frame for controls.
- Both sampling frames were first stratified by sex, followed by simple random sampling from each frame to proportionately select participants (based on ratio of males to females) to be enrolled in the study.
- After stratification by sex, a random sample of controls at baseline was used within each stratum to select three potential controls for every case to provide a large pool of potential participants for matching to cases, while maintaining the sex distribution of the participants.
- The controls were initially individually matched to cases 1:1 on age, sex, and time since ART initiation to improve comparability and to limit the effects of confounding variables, and to improve statistical efficiency in adjusted analyses.
- Using this strategy, cases and controls were drawn from the same source or study base, ensuring that both groups originated from the same population at risk of developing the outcome.

3.5 Pre-test of tools

A pre-test of the tools was done with 10% of the study sample (42 adults on ART) to determine the effectiveness of the data collection tools. The pre-test provided information about the clarity of the instruments, the ease of administering them and the time taken to administer them. This information was useful for refining the tools. The pre-test was conducted in a different Sub-County (Muhoroni County Hospital) to prevent the Hawthorne effect during the actual data collection.

3.6 Data collection

3.6.1 Data collection tools

The study made use of GPS enabled tablets with interviewer-administered pre-programmed structured questionnaires. The questionnaire included items assessing perceived drivers and dimensions of water insecurity, which were developed and categorized in alignment with the SEM to capture structural, community, household, and individual-level influences. Validated tools/instruments were also administered, including the Household Water Insecurity Experiences Scale (HWISE), Individual Water Insecurity Experiences Scale (IWISE), the Household Food Insecurity Access Scale (HFIAS), a Generalized Anxiety Disorder Assessment (GAD-7) tool, and a Patient Health Questionnaire (PHQ-9) tool to collect quantitative data. Water samples for quality testing were collected using sterilized 1-liter bottles per sample. Interview guides were used to collect qualitative data. The tools were applied as follows:

- The GPS was used to collect de-identified location information on household locations, health facilities and water sources (with no identifiable information about participants).
- The HWISE is a 12-item cross-culturally validated tool for identifying and scoring **individuals in households** that have water insecurity and the extent of the water insecurity. It has a **four-week recall period** but can be adapted to suit the study objectives. It evaluates observable indicators/manifestations of water access and use, each of which depends on and thus reflects water availability and stability. It is best for measuring the status of household water insecurity and was used to determine the prevalence, scores, and households that had water insecurity in the baseline study. The HWISE showed an excellent internal consistency in the study population (Cronbach's $\alpha = 0.95$).
- The 12-item IWISE measures **individual experiences** of water insecurity over a **12-month recall period**. It is designed to enhance understanding of the granular consequences of water insecurity. It measures the water insecurity of individuals in relationship to its potential determinants and consequences and was therefore more appropriate to measure the exposure – water insecurity, for the case-control study.

  For both the HWISE and IWISE, the scores range from 0-36 with four response categories per question: 0, 1, 2, and 3 to correspond to never, rarely (1 -2 times), sometimes (3 – 10

times), and often or always (more than 10 times) respectively. The score for each household/individual is then calculated by summing responses to each question for the household/individual. A household/individual with a score ≥ 12 is considered water insecure. The scores can further be categorized to determine severity of water insecurity: (0–2): no-to-marginal, (3–11): low, (12–23): moderate, and (24–36): high water insecurity (Frongillo et al., 2024).

- The HFIAS is a nine-item validated tool that helps to capture the experience of household food insecurity by quantifying the experience through a survey and summarizing it on a scale. It is used to assess the prevalence of household food insecurity in terms of access with a four-week recall period. The first part of each question has a Yes/No response to each experience, while the second part rates the frequency of the experience as 1,2, or 3 to correspond to rarely (once or twice in the past four weeks), sometimes (three to ten times in the past four weeks), and often (more than ten times in the past four weeks). Food insecurity not only co-occurs with but could also be a causal intermediate in the association between water insecurity and HIV treatment outcomes. In this study, it was used to determine the household food insecurity status of participants, since it was identified as a potential mediator in the conceptual framework.
- The GAD-7 is a seven-item instrument validated for, among other populations, primary care patients. It is used for assessing the severity of generalized anxiety disorder symptoms with a two-week recall period. The GAD-7 score is calculated by assigning scores of 0, 1, 2, and 3, to the response categories of "not at all," "several days," "more than half the days," and "nearly every day," respectively, and then adding together the scores for the seven questions. GAD-7 total score for the seven items ranges from 0 to 21. Scores of ≤4, 5-9, 10-14, and 15-21 correspond to minimal, mild, moderate and severe anxiety respectively. In this study, it was important to measure anxiety because of the association between resource insecurities and mental ill-health and this latter's conceptual role as a potential causal mediator/intermediate variable.
- PHQ-9 is a tool for measuring depression. The depression score is obtained by summing up scores for each question per individual, with total scores of 0-4, 5, 10, 15, and 20 representing cut points for none/minimal, mild, moderate, moderately severe, and severe

depression respectively. Question 9 is a single screening question on suicide risk. Any patient who answered YES to question 9 was immediately after the interview referred to their respective comprehensive care center (CCC) for suicide risk assessment by an individual who is competent to assess this risk. In this study, it was important to measure depressive disorder because of the established association between resource insecurities and mental ill-health among PWH (Miller et al., 2021b); and the conceptual role of depression ad a potential intermediate variable.

- Digitized and paper interview guides, electronic recorders and field notes were used for collection of qualitative data.
- The data collection instruments were all translated from English to Kiswahili and Luo, then back-translated to ensure integrity to the original meaning.
- Water samples for quality testing were collected using sterilized 1-liter airtight containers.

3.6.1.1 Reliability of study tools

The test-retest method of ascertaining internal consistency was used to establish reliability of survey instruments. The tools were administered twice, 2 weeks apart to the same group of identified adults on ART in a comparable location (Muhoroni sub-county) outside the study area. The scores from the 2 time periods were correlated and a Pearson r's score equal to or greater than 0.8 was considered acceptable. The Pearson's r for this study's questionnaire was 0.88.

3.6.1.2 Validity of study tools

The validity of study tools (household questionnaire, Appendix 1) was determined using Content validity Index (CVI). This refers to the degree to which a tool has an appropriate sample of items for the construct being measured (Polit & Beck, 2021). In this study, CVI was ascertained by using two study subject experts to rate every question in the questionnaire and interview guide on relevance and clarity. The experts independently rated each item as either 1 = Not relevant, 2 = Somewhat relevant, 3 = Quite relevant, and 4 = Highly relevant. The CVI was then obtained by dividing the number of items rated 3 or 4 by both judges by the total number of items in the tool. A CVI of 0.8 was considered acceptable. The CVI for this study's questionnaire was 0.92. Study tools that have already been cross-culturally validated for use in the study area (water and food

insecurity scales, GAD-7, PHQ-9) were used without being subjected to further quality assurance for this study.

3.6.2 Data collection procedures

For the first objective of characterizing the drivers and dimensions of water insecurity, a cross-sectional survey was done using a household questionnaire and the HWISE to measure participant sociodemographic characteristics and determinants of water insecurity and water insecurity score respectively.

Beginning with household socio-demographics, the household questionnaire mainly quantified the general manifestation (dimensions) of water insecurity experienced, potential distal/underlying drivers of water insecurity such as spatial, structural and socio-economic drivers, and the perceived influence of water insecurity on the health, livelihoods, hosing and displacement of participants.

The HWISE quantified experiences over diverse components of household water insecurity to address the household water access, availability, adequacy, and use.

All interviews were researcher-administered at the household level, and each household was geo-referenced. The study used the Global Positioning System (GPS) to collect spatial point data showing the location of households with de-identified adults on ART information. Additionally, there was geo-referencing and triangulation of surface and ground water sources.

Water Sampling for quality analyses

Water samples were collected from household and communal water sources used by participants in the study. A total of 34 samples were obtained from surface water sources, groundwater sources (including boreholes, wells, and natural springs locally referred to as soko), rainwater storage systems, and a piped community supply point.

Each sample was collected using sterilized 1-liter high-density polyethylene (HDPE) bottles. The bottles were clearly labeled with sample ID and location details. To preserve microbial and chemical integrity, samples were immediately placed in ice-cooled portable cooler boxes maintained at approximately 0–6 °C, protected from direct sunlight. The samples were transported within 5 hours to the lab.

For the second specific objective on lived experiences of water insecurity, an exploratory formative study was conducted using qualitative techniques. The qualitative study included seven FGDs, each with about 6-8 participants, and 21 IDIs. The total number of interviews was determined through data saturation, when no new information was emerging from successive interviews, and the study provided maximum granular data on the lived experience of the phenomenon. The IDIs and FGDs were stratified by gender and age.

Focus group participants were mobilized by peer leaders and mentor mothers (who already work with and have familiarity with the target population) to a central location - the respective study site health facility. One or two focus groups was conducted per day depending on the availability of participants. All IDIs were conducted at the household or at a location of the participant's choice with due regard to privacy. Two to three IDIs were conducted per day. All interviews were recorded using electronic voice recorders and interview notes taken. Gender sensitivity was ensured during the interviews, so that men were interviewed by male and women by female interviewers respectively. The interviews were conducted using FGD and IDI guides (Appendix IV) and lasted between 60 to 90 minutes. Focus group participants were reimbursed for transport costs and time, and IDI participants were compensated for time.

The aim was to uncover the **mechanisms**, **narratives**, and **everyday realities** that explain how water insecurity interfered with:

- Medication adherence (e.g., skipping ART due to lack of water to swallow pills)
- Retention in care (e.g., missing appointments due to long hours spent fetching water)
- Physical and mental health (e.g., stress, fatigue, or depression related to water scarcity)
- Hygiene and sanitation-related vulnerabilities (e.g., inability to stay clean, leading to stigma or secondary infections)
- Gendered burdens (e.g., women disproportionately affected by water-fetching responsibilities that delay or interrupt care).

For specific objective three, which was to measure the association of water insecurity with HIV health outcomes, a fixed-cohort case-control study was done, with cases being adults on ART who met the case definition of HIV treatment outcomes matched on time since initiation of ART, age and gender to one control each without the HIV outcomes of interest. Recruitment of

cases was restricted to those who had been on ART for at least six months before the interview date. This was done to exclude those who would have been on treatment for less than six months since treatment initiation, for whom the treatment might not have resulted in stable virologic suppression, or consistent adherence patterns, since these had the potential to bias results. Cases were identified from the EMR line lists based on VL ≥200 copies/mL first, then the CD4 counts, opportunistic infections, and missed clinic visits where available on the EMR. They were recruited in batches to allow identification of matching controls. Interviews were conducted at the household, where an additional screening questionnaire was administered to verify outcome status of participants.

Clinical data of all sampled adults on ART with HIV treatment outcomes of interest were obtained from the MoH EMR. The controls were sampled from the same primary study base /underlying cohort of adults on ART that gave rise to the cases. The study base comprised adults on ART enrolled in care in the three study sites. Data on the cases and controls were obtained from MoH registers and EMR, while data on exposure to water insecurity were obtained by administering the IWISE after enrolment of both cases and controls to determine previous individual exposure to water insecurity. Participants were interviewed using the HFIAS, since water and food insecurity co-occur, while the GAD-7 and PHQ-9 were used to measure the mental health status of respondents.

3.6.3. Measurement of key variables

- Water insecurity

  Water insecurity was measured using Household Water Insecurity Experiences Scale (HWISE) and the Individual Water Insecurity Experiences Scale (IWISE) for specific objectives one and three respectively. The two scales, commonly referred to as the WISE scales were designed and validated for use across diverse contexts, and provide standardized measures of water insecurity at the household and individual levels, respectively, with total scores ranging from 0 to 36 (S. L. Young, Boateng, et al., 2019; S. L. Young et al., 2021). Although an initial cut-off of ≥12 (range 0-36) was proposed to indicate the presence of water insecurity, researchers have since recommended establishing four additional thresholds to capture varying degrees of severity according to increasing ordinal categories: no-to-marginal (0–2), low (3–11), moderate (12–23), and high (24–36) water insecurity (Frongillo et al., 2024). Therefore,

household water insecurity was analyzed as a binary and also as a categorical variable to report a granular prevalence and severity of household water insecurity experiences.

- HIV treatment outcomes

  In this study, the observation of any of the following constituent outcomes in adults on ART constituted an observation of the dependent variable:

  - Sub-optimal viral suppression (≥200 copies/mL) as at the most recent test, that is, HIV viral load starting from 200copies/mL and above (NASCOP, 2022).
  - Most recent CD4 count <200 cells/mm^3 (NASCOP, 2022), where immunologic data was available.
  - AIDS-defining illnesses/opportunistic infections in the 12 months prior to the study.
  - Missed clinic visits within the 12 months prior to the interview date.

  The period of 12 months was chosen to tally with the exposure variable (IWISE) which was also assessed within a similar time period. In addition to clinical information from respective health facilities, an HIV treatment outcomes screening tool was additionally administered to obtain participant self-reports of any of these outcomes.

  A composite HIV treatment outcome variable was constructed by combining four clinically relevant indicators of HIV treatment status. Each indicator representing a constituent outcome of interest, for example, missed clinic visit, was first coded as a binary variable, with **0** indicating the absence and **1** indicating the presence of the outcome, according to the operational definitions.

  The four binary variables were then combined in STATA using a "presence of any constituent outcome" approach. Participants with the presence of at least one constituent outcome (viral load ≥200 copies/mL, CD4 count <250 cells/mm³, presence of an opportunistic infection, or a missed scheduled clinic appointment) were classified as **cases** (poor HIV treatment outcome), whereas those with none of the adverse indicators were classified as **controls**. Thus, the composite outcome was a dichotomous variable indicating the presence of any outcome or absence of all outcomes across the four constituent indicators.

  The use of a composite outcome was appropriate for two key reasons: one, it helped to enhance statistical efficiency by allowing for a smaller but well-powered sample size and did away with the requirement for a follow-up period to observe the outcome, therefore, more efficient. Two,

considering that the study population comprised of adults on ART among whom individual adverse treatment outcomes are relatively rare, separation and measurement of individual outcomes was not feasible since some outcomes would have very small numbers of observations/sparse cell counts of observations, making it difficult to attain the required variability and leading to destabilized and difficult to interpret regression models. Even with the recommended use of multinomial regression for multiple outcomes, the low prevalence of individual outcomes (for example <5 observations of opportunistic infections) would have resulted in a high lack of precision of estimates (with very wide confidence intervals) and problems with model convergence.

Importantly, the application of a composite outcome as the dependent variable reflects the clinical reality of HIV care, where treatment failure is often depicted by multiple manifestations rather than a single isolated endpoint (Panel on Antiretroviral Therapy and Management of Children Living with HIV, 2025). For that reason, the composite measure captures a broader profile of what constitutes an unsuccessful HIV treatment outcome while maintaining analytic robustness.

- Secondary measures included:
  - ART access and adherence, measured using binary Yes/No responses
  - Mental health status, measured separately using anxiety (GAD-7) and depression (PHQ-9) scales
  - Food insecurity status measured using the Household Food Insecurity Access Scale (HFIAS)
  - Water related illnesses, measured using binary Yes/No responses

- Additional covariates were selected based on theoretical relevance and prior empirical literature. Variables were categorized according to the Socio-Ecological Model (SEM) to reflect the multi-level determinants shaping water insecurity and HIV treatment outcomes.
  - At the structural level, variables included perceived environmental and infrastructural drivers of water insecurity, such as drought, flooding, groundwater conditions (e.g., water table issues), and infrastructure limitations.
  - At the community level, variables captured characteristics of shared water systems and local water environments. These included distance to water sources, type of water source, perceived

water quality, and laboratory-tested water contamination indicators (Microbiological and physicochemical parameters).

- At the interpersonal (household) level, variables included type of housing, household income and household size, reflecting economic capacity and intra-household resource demands.
- At the individual level, variables included age, sex, marital status, employment status, and education level. Age and sex were treated as a priori confounders in this study based on existing evidence that both are independently associated with water insecurity and HIV treatment outcomes. Specifically, women are more likely to experience water insecurity due to gendered roles in water collection and household responsibilities, while also facing distinct vulnerabilities in HIV care. Similarly, age influences both exposure and outcome, as younger and older adults may differ in access to resources, care-seeking behaviors, and treatment adherence.

- For Objective 1 (drivers and dimensions of water insecurity), structural, community, interpersonal, and individual-level variables were examined as potential predictors of water insecurity. For Objective 3 (association between water insecurity and HIV treatment outcomes), individual and interpersonal-level variables were treated as potential confounders and adjusted for in multivariable models. Structural and community-level variables were examined descriptively and in determinant analyses but were not included as covariates in the primary association models to avoid overadjustment.
- Food insecurity, mental health status, and ART adherence were conceptualized as potential causal intermediates in the pathway linking water insecurity to HIV treatment outcomes and were therefore analyzed separately in pathway-oriented models rather than included in models estimating the total effect of water insecurity on HIV treatment outcomes.

3.7 Quality assurance

Quality assurance involved considerations for improving internal and external validity.

3.7.1 Internal validity

Internal validity refers to the degree to which the observed associations between exposure and outcome are true and not attributable to systematic error. In this observational mixed-methods study that comprised a baseline cross-sectional survey, a qualitative exploratory study, and a case-control study, efforts were made at every stage to strengthen internal validity and minimize bias.

To that end, several threats to internal validity were considered and addressed in the following ways:

1) Selection Bias

Selection bias arises when the participants selected into the study differ systematically between comparison groups, potentially distorting the exposure–outcome relationship. In the baseline cross-sectional study, potential selection bias was reduced by two considerations: first, the use of systematic sampling with implicit stratification by gender, based on ART line lists from the participating study sites. Second, the choice of County hospitals as study sites was based on the fact that those hospitals had CCCs, HTS, and EMR, and also served large volumes of clients from all over Kisumu County.

For the qualitative study, selection bias was addressed by employing purposive sampling with maximum variation, which enabled the deliberate inclusion of participants with diverse experiences of water insecurity and HIV care. Participants were selected to capture variation across key characteristics such as gender, age, and socio-economic context thus reducing the likelihood of systematically excluding relevant perspectives. In addition, recruitment was conducted across multiple sites and participant groups, which helped to broaden the range of experiences represented in the study.

In the case-control component, this bias was minimized by drawing both cases and controls from the same clinical population of adults receiving HIV care from public health facilities in Kisumu County. Cases were defined primarily based on documented HIV viral load (≥ 200 copies/mL), then based on having any of the other three case definition outcomes among individuals who had been on ART for at least six months, while controls were those with viral load >200 copies/mL, with none of the other three case definition outcomes. The cases and controls were matched on age, gender, and time since ART initiation to ensure comparability. These considerations helped to ensure representativeness of the sample and collectively reduced the likelihood of systematic differences between those included in the study and the broader population of adults on ART within Kisumu County.

2) Information Bias

Information bias, including recall and interviewer bias, poses a significant threat to internal validity, particularly in observational studies relying on self-report.

a) Recall Bias

Recall bias was a concern in the cross-sectional and case-control studies, as participants were asked to recall past experiences of water insecurity and disruptions to HIV care. To mitigate this, cross-culturally validated scales with bounded recall periods were used to anchor responses to recent and past concrete events (e.g., "In the past four weeks, in the last 12 months…").

b) Interviewer Bias

To limit interviewer bias, all data collectors underwent rigorous training on standardized administration of tools, neutrality in questioning, and confidentiality. For qualitative data collection, trained facilitators used pilot-tested interview guides, and all sessions were audio-recorded and transcribed verbatim to ensure that data analysis reflected participant voices rather than interviewer interpretations. Regular supervision and inter-rater reliability (IRR) tests further minimized systematic researcher effects during coding. The IRR for the qualitative study was 85%.

3) Confounding

In observational studies, confounding occurs when the relationship between the exposure and the outcome is distorted by a third variable, the confounder, which is related to both the exposure and the outcome. In this study, confounding was a threat to internal validity; given the complex social and environmental determinants of both water insecurity and HIV treatment outcomes.

In the cross-sectional study, confounding was addressed analytically through multivariable regression models that adjusted for known and suspected confounders, including age, sex, marital status, household size, level of education, and household income. These covariates were identified through literature and their confounding role determined using Directed Acyclic Graphs (DAGs) (Figure 3.3). The DAG showed the confounders, causal intermediates, exposed biasing paths and showed the minimal sufficient adjustment sets for estimating the total effect of water insecurity on HIV treatment outcomes.

In the qualitative study, triangulation of data sources enhanced interpretive validity and helped identify patterns not attributable to single contextual or demographic variables.

In the case-control analysis, matching on age, sex, and time since ART initiation helped to minimize confounding by demographic and treatment-related factors that could independently influence both exposure and outcome. Additionally, stratified analyses and sensitivity tests were conducted to assess the impact of potential residual confounding.

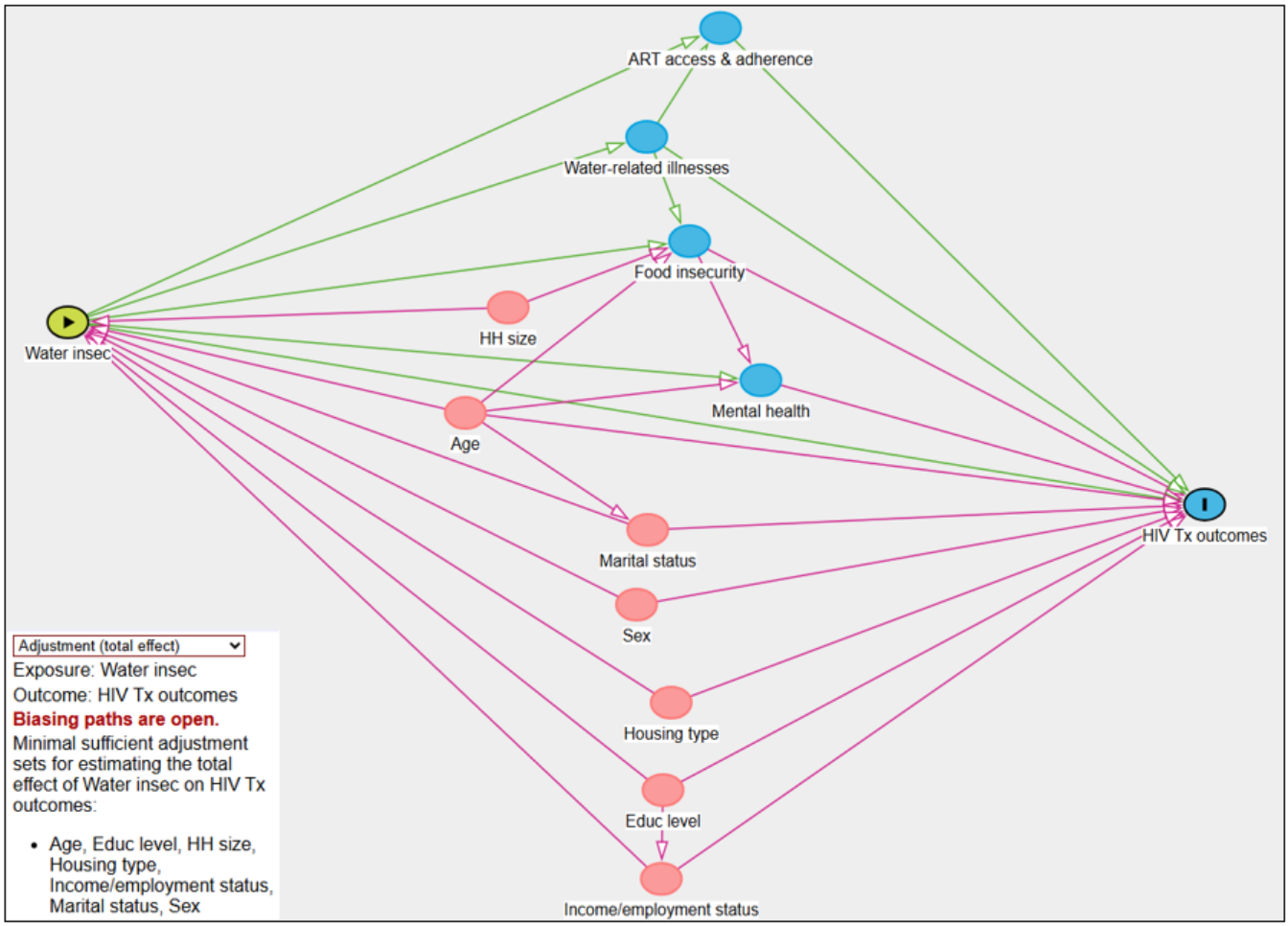


Figure 3.3: Directed Acyclic Graph (DAG) for identifying confounders and intermediate variables

The DAG shows the minimum adjustment sets for estimating the total effect of water insecurity on HIV treatment outcomes. The variables with pink nodes represent potential confounders which are upstream socio-demographic and structural factors that may influence both exposure to water insecurity and HIV treatment outcomes. For example, low socioeconomic status (captured through education, income/employment status, and housing) can constrain reliable access to water, and at the same time limit the resources needed by PWH to maintain consistent HIV care. Similarly, factors like age, sex, and marital status can influence both vulnerabilities to water insecurity and HIV care engagement. Household size similarly reflects underlying demand and utilization of

resources within the home, affecting both water dimensions and treatment continuity. On the other hand, the variables with blue nodes like food insecurity, water-related illnesses, mental health, and ART access and adherence work more as intermediate variables because they lie along the causal pathway (indirect effect) through which water insecurity affects HIV treatment outcomes. For example, water insecurity can worsen food insecurity and increase exposure to water-related illnesses, which in turn undermine mental health and the ability to consistently access and adhere to ART, and potentially result in poor HIV treatment outcomes.

4) Sparse data bias

Sparse-data bias occurs when small numbers of observations in one or more exposure–outcome cells lead maximum likelihood logistic regression to produce unstable and often exaggerated estimates of association. While sparse data was not significant in the cross-sectional study, for the case-control study, some exposure/explanatory categories contained relatively small numbers of observations, creating the potential for sparse-data bias and instability in maximum likelihood estimates from logistic regression models. To address this possibility, Firth's penalized logistic regression was conducted as a sensitivity analysis. Penalized likelihood estimation reduces small-sample bias and improves the stability of parameter estimates in the presence of sparse data or quasi-complete separation. The similarity between penalized and standard logistic regression estimates after the sensitivity analysis confirmed that the observed associations were robust and unlikely to be driven by sparse-data bias.

5) Reverse Causality

Reverse causality refers to a situation where the outcome influences the exposure. In this study, reverse causality was a concern in both the cross-sectional and case-control studies. For example, HIV care disruption and resultant illness might worsen household economic status, leading to water insecurity, rather than water insecurity causing treatment interruptions. While temporality, and therefore, causality could not be inferred due to the observational study design, analyses were cautious not to over-interpret associations. Based on the DAG, the identified potential intermediate variables, such as mental health, food insecurity, and ART access and adherence were measured to account for indirect effects. Additionally, findings were integrated with qualitative insights that provided temporal narratives of possible causality. The qualitative data, which included participants' lived experiences of water insecurity, offered rich contextualization of how water

insecurity evolved prior to or concurrently with treatment interruptions, further informing interpretation.

3.7.2 External validity

External validity refers to the extent to which the study findings can be generalized beyond the study population to other settings, populations, or time periods. In this study, generalizability was supported through deliberate sampling strategies and the inclusion of a representative sample of adult PWH on ART across multiple sites in Kisumu County. The baseline cross-sectional survey achieved a high response rate, with 434 out of the targeted 443 participants enrolled (98% attainment), enhancing the robustness of estimates regarding the drivers and dimensions (determinants) of water insecurity. The sample included both men and women across a range of age groups, socioeconomic backgrounds, and geographic contexts (rural and semi-rural), increasing the applicability of findings to other populations of PWH in similar water-insecure and climate-vulnerable regions, particularly in sub-Saharan Africa. Similarly, the case-control study enrolled 356 of the targeted 382 participants (93% attainment), drawing cases and controls from the same underlying study base to ensure internal consistency while maintaining population diversity.

However, some limitations to external validity remain. First, all participants were drawn from public HIV care facilities, potentially excluding those receiving care from private or informal sources. Second, the study was conducted in a region adjacent to Lake Victoria, where unique hydrological and ecological dynamics may differ from other parts of Kenya or the continent. Lastly, while the qualitative data added rich contextual depth and transferability, its interpretive insights are not transferrable beyond the study population, and the observational study design is a limitation for establishing causality. Overall, the findings provide valuable evidence for similar settings but should be applied cautiously to populations of PWH with substantially different environmental, health system, or social contexts.

3.8 Data management and analysis

Data were managed and analyzed using STATA vs 17, MS Excel, and Dedoose for quantitative and qualitative data respectively.

Participant quantitative data were collected electronically using GPS-enabled tablets and synchronized to the Research Electronic Data Capture (REDCap) platform for creating and managing surveys and databases primarily for clinical and translational research. The data were then exported to Excel and STATA for cleaning and analyses as appropriate. Qualitative data was initially analyzed using Dedoose.

3.8.1 Specific objective 1

3.8.1.1: Baseline cross-sectional study

i. Descriptive and bivariate analyses of participants' sociodemographic characteristics were conducted, stratified initially by sex. The characteristics were summarized by sex to describe the composition of the study population and to explore potential sex-based differences in sociodemographic factors that may influence water insecurity. Descriptive comparisons of participant characteristics by water insecurity status were conducted to identify patterns that may inform model building and interpretation. This stratification was intended to highlight the social and structural differences between water secure and water insecure households. Number (n) and percent were reported for categorical variables, including p-value from Pearson's chi-squared test. For numerical variables, mean, standard deviation (SD) and p-value for two sample t-test for normally distributed variables, or median, interquartile range and p-value for Mann-Whitney U tests for skewed distributions were presented. Descriptive statistics were also used to analyze the perceived drivers and dimensions of water insecurity reported by participants. The prevalence of each determinant (driver or dimension) was summarized as frequencies and proportions. Results were presented using graphs.

ii. Secondly, to estimate associations between predictor variables and household water insecurity (defined as a HWISE score ≥12), a multilevel mixed effects logistic regression model was used. Given the hierarchical structure of the data whereby individual participants were nested within three health facilities, a two-level modelling approach was used to account for intra-cluster correlation (ICC). Specifically, random intercepts for health facilities were included to allow the baseline log odds of water insecurity to vary across facilities, accounting for unobserved heterogeneity that might influence participants' risk of water insecurity at the facility level. Fixed effects were specified for all individual-

level predictor variables and covariates to estimate population-averaged associations. Random slopes were not included, as it was not expected that the relationship between individual-level predictors and water insecurity would vary significantly across facilities, given the relatively small number of clusters (n = 3). The ICC was effectively zero (ICC = 4.6×10^{-32}), indicating negligible between-facility variation in household water insecurity.

iii. To determine the sociodemographic and community-level predictors of water insecurity using regression analyses, mixed effects models were used to account for clustering by facility/study site. First, univariate regression analyses were conducted. Variables with a p-value ≤0.10 in the univariate analysis, or those deemed as having clinical relevance to HIV outcomes (even if observed in only one level of a categorical variable) were included in the multivariable model. The adjustment variables were identified using DAGs (Figure 3.3). To ensure that the models were stable and to maximize statistical power, the reference for each categorical covariate was set to the modal group, that is, the category that had the highest frequency or number of observations. This modelling approach helped to make results more reliable and consistent so as to produce measures of association (ORs/AORs) and p-values that were representative of the actual patterns in the data, instead of getting skewed by smaller reference groups which would cause model instabilities.

3.8.1.2 Water quality sub-study

Water samples were analyzed for quality at IMARA Analytical Laboratories in Kericho County, a certified environmental testing facility, for comprehensive analysis. The laboratory was visited physically and determined to have the capacity to test and provide unbiased reports of the water quality based on the samples collected and issued for testing.

Laboratory analyses

Water quality analyses involved:

i. Microbiological analyses on levels of Total Coliforms and *Escherichia* coli (E-coli) using pour plate techniques with Violet Red Bile (VRB) agar for coliform enumeration and Eosin Methylene Blue (EMB) agar for *E. coli* detection and enumeration.

ii. Physicochemical analyses to check for the presence of dissolved chemicals, minerals, total dissolved solids, the pH, and turbidity against WHO and KEBS standards.

All tests followed standardized protocols, with results compared to World Health Organization (**WHO**) and Kenya Bureau of Standards (**KEBS**) limits to assess safety for PLWH.

Microbiological Analysis

Microbiological analysis was undertaken to assess and quantify the presumptive presence of TCs and *E. coli* in the water samples using a selective, culture-dependent pour-plate technique. A 1.0-mL aliquot of each sample was inoculated into the respective culture medium.

Total coliforms were enumerated using Violet Red Bile (VRB) agar, prepared according to the laboratory standard operating procedures and incubated at 35 ± 2°C for 24 hours. Presumptive TC colonies were identified by their characteristic dark purple-red appearance with a peripheral bile-salt halo. *E. coli* was assessed using Eosin Methylene Blue (EMB) agar and incubated under the same conditions; presumptive colonies were identified by their characteristic dark appearance with a green metallic sheen. Microbial density was calculated as CFU/100 mL = (number of colonies/volume plated in mL) × 100; since 1.0 mL was plated, counts were multiplied by 100.

Physicochemical Analysis

Physicochemical analyses encompassed 23 physical and chemical parameters (Appendix VII), employing standardized techniques for precision.

Physical quality parameters included pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), and turbidity. The pH, EC, and TDS were measured potentiometrically using calibrated probes (Hanna Instruments HI98129) and conductivity meters (Hach HQ40d). Total suspended solids were determined gravimetrically after filtration, while turbidity was assessed nephelometrically with a Hach 2100Q portable turbidimeter (Hach Company, USA) and reported in Nephelometric Turbidity Units (NTU), the standard unit describing how much suspended particles scatter light in water.

Chemical parameters included major ions, trace metals, and nutrients. Chlorides and bicarbonates were determined using argentometric and acid-base titration, respectively.

Nitrates (NO_3^-) were analyzed titrimetrically, and ammonium nitrogen (NH_4-N) was measured using the Kjeldahl method for nitrogen content. Sulfates and phosphates were quantified using Inductively Coupled Plasma - Atomic Emission Spectroscopy (ICP-AES; PerkinElmer Optima 8000), an analytical technique that excites atoms in plasma and measures their light emissions to

quantify metals and major ions with high sensitivity. Trace and major metals (Cd, Zn, Ca, Mg, K, Fe, Mn, Na, Al, B, Cu, Pb) were also analyzed using ICP-AES.

Water quality data analysis

i. The water quality parameters were summarized using descriptive statistics. Because microbial counts are typically skewed, results were summarized using medians and ranges. Physicochemical parameters were summarized using observed ranges across sampled water sources. Measured values were compared with recommended drinking water guideline values, and the number and proportion of samples exceeding these limits were calculated.

ii. Microbiological results were summarized by water source category to examine differences in contamination patterns across surface water, groundwater, rainwater storage, and piped sources, as microbial contamination is strongly influenced by contamination pathways related to source exposure and protection (e.g., runoff, sanitation leakage, and animal activity) (WHO, 2022a).

iii. Physicochemical parameters were summarized across all samples because many chemical characteristics reflect both underlying hydrogeochemical processes and anthropogenic influences, including surface runoff and leaching of chemicals from agricultural activities into surface and ground water respectively, as well as the direct discharge of chemical-laden industrial effluents into water bodies (Zhang et al., 2024). Presenting physicochemical results as overall ranges and guideline exceedances also allowed clearer interpretation given the large number of parameters (23) measured.

Water quality control and standards

All analyses were performed in triplicate, with results compared to WHO and KEBS drinking water standards (e.g., pH 6.5–8.5 for lake samples, 5.5–9.5 for other sources; nitrates ≤10 mg/L; E. coli 0 CFU/100 mL) to evaluate water suitability for consumption by PLWH. These benchmarks provided the reference criteria to determine the potability and safety of each sample, guiding the interpretation of both microbial and chemical contamination risks.

Table 3.2 Water quality parameters, analytical methods, and WHO & KEBS guidelines

Parameter type	Parameter(s)	Analytical method	Instrument(s)	Reporting unit	WHO/KEBS guideline value*
Microbiological	Total coliforms, E. coli	Membrane filtration, selective media incubation	—	CFU/100 mL	0 CFU/100 mL
Physical	pH	Potentiometric measurement	Hanna HI98129, Hach HQ40d	pH units	6.5–8.5 (lakes), 5.5–9.5 (others)
	Electrical conductivity (EC)	Potentiometric	Hach HQ40d	µS/cm	—
	Total dissolved solids (TDS)	Potentiometric	Hach HQ40d	mg/L	≤1000 mg/L
	Total suspended solids (TSS)	Gravimetric after filtration	—	mg/L	—
	Turbidity	Nephelometric	Hach 2100Q	NTU	≤5 NTU (≤1 NTU recommended)
Chemical	Chlorides	Argentometric titration	—	mg/L	≤250 mg/L
	Bicarbonates	Acid–base titration	—	mg/L	—
	Nitrates (NO_3^-)	Titrimetric	—	mg/L	≤10 mg/L
	Ammonium nitrogen (NH_4-N)	Kjeldahl method	—	mg/L	≤0.5 mg/L
	Sulfates, Phosphates	ICP-AES	PerkinElmer Optima 8000	mg/L	Sulfates ≤250 mg/L, Phosphates ≤5 mg/L
	Metals (Cd, Zn, Ca, Mg, K, Fe, Mn, Na, Al, B, Cu, Pb)	ICP-AES	PerkinElmer Optima 8000	mg/L	Varies by metal (e.g., Pb ≤0.01 mg/L, Cd ≤0.003 mg/L, Fe ≤0.3 mg/L)

3.8.2 Specific objective 2: Exploratory qualitative study

Thematic analysis, with content coding, was employed for qualitative data analysis for specific objective two, using an integrated deductive-inductive approach followed by framework analysis for pathways development.

i. Initial codes were developed based on the study's qualitative objective and interview guides, while analysis remained open to generation of new codes and themes that emerged inductively from the data.

ii. First, audio recordings were transcribed verbatim then translated to English for a total of 28 transcripts comprising 7 FGDs (5 female, 2 male) and 21 IDIs (8 male, 13 female). Initial familiarization with the data was done whereby some emerging broad themes that seemed to address the research question were noted to guide the coding process.

iii. A structured codebook was developed to guide consistent code application during analysis. It was made up of the deductively derived codes from topic outlines of the interview guides. The codebook had six columns with the code name, code labels to show depth (0 for parent/main code and 1 for child/sub-code), code definition, when to use (inclusion criteria), when not to use (exclusion criteria), and example quotes.

iv. Each transcript was read and reviewed for coherence then uploaded into the Dedoose (version 10.0.35; SocioCultural Research Consultants) for coding. The Dedoose software was used to manage the analysis of de-identified qualitative data.

v. A random sample of seven transcripts (25%) were double coded by a different researcher for consensus as a way of increasing the reliability of the identified codes (Creswell & Poth, 2016).

vi. Inter-rater reliability (IRR) test was then conducted using a purposive sample of two FGDs and two IDIs, representing approximately 15% of the full dataset. A total of 335 excerpts from the sampled transcripts were coded, and the IRR determined {IRR = agreements divided by (agreements + partial agreements + non-agreements)}. The test yielded an IRR of 85.3%, reflecting excellent agreement according to Cohen's Kappa benchmarks (κ = 0.81–1.00). Coding discrepancies were resolved through discussion and consensus prior to finalizing the codebook.

vii. Final coding was applied across the full dataset in Dedoose and agreed upon codes on the lived experience of water insecurity were extracted, organized, and reviewed. Dedoose's code co-occurrence matrices and memoing tools were used to identify intersections between codes and inform category development.

viii. Recurrent, salient, emerging themes and their interrelationships were explored to document the lived experience of water insecurity by study participants, and the lived experiences used to develop a novel conceptual model (Figure 4.7) of identified pathways from water insecurity to HIV outcomes, anchored on the Capability Framework.

Next, a framework analysis approach was used to develop explanatory mechanistic pathways linking water insecurity to HIV treatment outcomes. Framework analysis is a systematic method of qualitative data analysis that facilitates the organization, mapping, and interpretation of data to identify patterns, relationships, and identifying how experiences are connected within each participant's accounts of a phenomenon and across multiple participants' accounts to explain outcomes (Klingberg et al., 2024)).

ix. Using the derived themes from the thematic analysis, the process started by indexing the themes according to the roles they played in water insecurity (Figure 3.3). Specifically, themes were reclassified into analytic categories reflecting their position in the causal process, including structural drivers like environmental vulnerability; exposure dimension, for example limited access to water; mediating mechanisms, for example, psychosocial stress, physical illness, and economic strain; and outcomes, for example, disruptions in HIV treatment engagement like missed or delayed doses due to lack of water or time displacement while fetching water.

x. A framework matrix was developed next, and experiential data summaries from participants were organized to compare and synthesize similarities and disparities. Through this detailed process of charting, patterns of co-occurrence and interaction between themes were examined.

xi. Relational linkages between themes were identified, including how certain experiences triggered, reinforced, or exacerbated other experiences within participants' accounts, for example, lacking water leading to challenges with cooking and thus missing meals.

xii. The resulting relationships were then mapped and clustered into mechanism-based groupings (Table 3.2), showing for example, the pathway from gender roles to missed clinic visits. The pathways were an illustration of how different dimensions of water insecurity operated together to influence health behaviors and outcomes.

xiii. Through iterative comparison and abstraction, these clusters were synthesized into a set of explanatory pathways, each representing a distinct but interrelated mechanism through which water insecurity influenced HIV treatment outcomes.

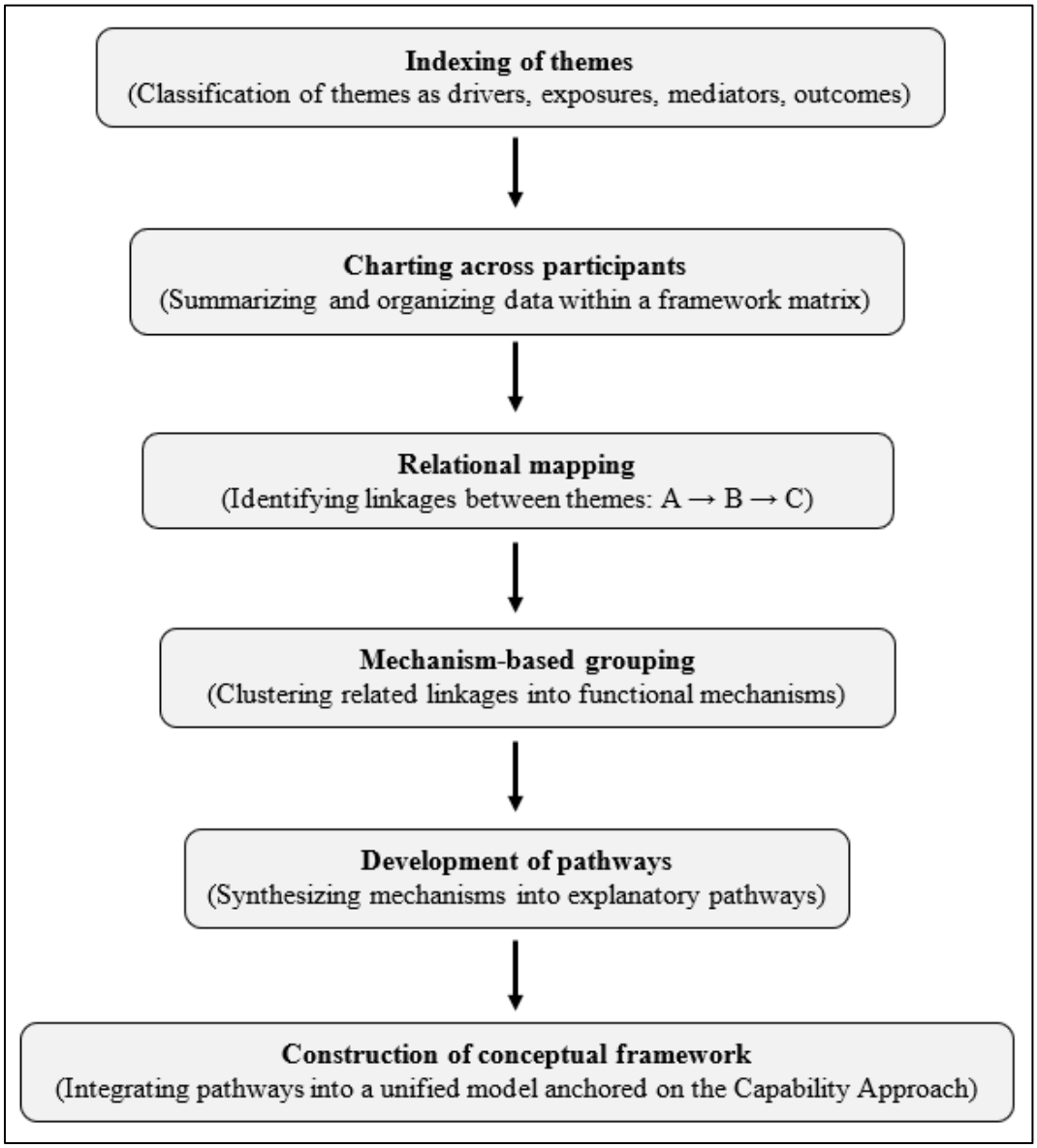


Figure 3.4: Framework analysis flowchart

Table 3.3: Clustering relationships into functional mechanism groups

Theme	Mechanistic pathway (from data)	Cluster
Environmental vulnerability	Flooding → exposure to contaminated water → illness → treatment disruption	Physical Health
Environmental vulnerability	Prolonged dry season → water scarcity → exposure to contaminated water → water-related illnesses → treatment disruption	Physical Health
Limited access to water	Water scarcity → use of unsafe water → water-related infections → poor adherence	Physical Health
Limited access to water	Time spent fetching water → missed clinic visits → treatment disruption	Resource insecurity
Unsafe water & illness	Unsafe water → recurrent illness → reduced functioning → poor HIV outcomes	Physical Health
Gendered norms & violence	Gender roles → water burden → time constraints → missed care	Gendered & Relational
Gendered norms & violence	Water collection → exposure to violence → injury/fear → treatment disruption	Gendered & Relational
Flood displacement	Flooding → displacement → loss of medication → missed doses	Environmental shocks and mobility
Flood displacement	Flooding → inaccessibility of clinics → missed visits	Environmental shocks and mobility
Livelihood & crop loss	Drought/flood → crop loss → income loss → inability to afford care → missed visits	Resource insecurity
Livelihood & crop loss	Time spent fetching water → reduced income → financial strain → poor adherence	Resource insecurity
Psychosocial stress	Water insecurity → stress/anxiety → forgetfulness → missed medication	Psychosocial
Psychosocial stress	Chronic worry → cognitive overload → delayed ART	Psychosocial
Treatment disruption	Lack of water → inability to take medication → skipped doses	Water-dependent dosing
Treatment disruption	Water + food insecurity → undernutrition → weakness → poor adherence	Physical Health
Treatment disruption	Lack of water → time displacement in search of water → interrupted schedule of medication → delayed doses	Water-dependent dosing

Tabel 3.4: Synthesized mechanisms with corresponding explanatory pathways

Pathway	Explanatory mechanistic pathways
Environmental shocks & mobility	• Flooding → displacement from homes → loss of shelter and stability → disruption of daily routines → missed ART doses • Flooding → loss or destruction of medication and clinic cards → inability to continue treatment → treatment interruption • Flooding → damaged infrastructure (roads, facilities) → inaccessibility of clinics → missed clinic visits • Displacement to overcrowded shelters → poor living conditions and instability → reduced capacity to maintain treatment routines
Physical Health	• Unsafe water → recurrent illness → reduced physical functioning → poor HIV outcomes • Flooding → exposure to contaminated water → illness → treatment disruption • Water insecurity → food insecurity → undernutrition → weakness → reduced adherence
Psychosocial	• Water insecurity → stress/anxiety → forgetfulness → missed ART doses • Chronic worry → cognitive overload → delayed medication • Competing demands (water + food) → mental burden → poor adherence
Gendered & Relational dynamics	• Gender norms → water burden → time constraints → missed clinic visits • Gendered roles→ reduced autonomy to prioritize medication → poor adherence • Water collection → exposure to violence → injury/fear → disrupted care • Delays in water collection → partner conflict/IPV → treatment interruption
Resource insecurity	• Drought/flood → crop loss → income loss → inability to afford care → missed visits • Water insecurity → food insecurity → inability to take ART without food → adverse side effects (e.g., nausea, heartburn) → skipping of doses → intentional or forced non-adherence • Time spent fetching water → reduced livelihood activity → financial strain → poor adherence • High water costs → trade-offs (water vs food vs transport) → missed clinic visits
Water-dependent dosing	• Lack of water → inability to meet immediate dosing requirements or prepare food → delayed or skipped doses • Water scarcity → too much time spent sourcing for water→ skipped/delayed ART doses → treatment interruption • Water scarcity → prioritizing water collection over clinic visits → missed appointments and delayed refills

The resulting pathways were grounded in participants' lived experiences while providing a structured representation of the processes linking structural and environmental conditions to health outcomes. This approach enabled the transition from descriptive thematic findings to an explanatory conceptual model that integrated the SEM and CA, capturing both the complexity and interrelated nature of pathways through which water insecurity affects HIV treatment continuity among adults on ART in Kisumu County.

3.8.3 Specific objective 3: Case-control study

Exposure to water insecurity was compared between cases and a strategic random sample of controls and an estimate of the association between water insecurity and HIV treatment outcomes was derived. As earlier indicated, participants must have been on care for at least six months. Including individuals on ART for less than six months could introduce misclassification of outcome status, specifically, it would result in non-differential misclassification of HIV treatment outcomes, as early viral rebound or care disruption might reflect the natural course of early treatment adjustment rather than a true disruption due to structural or behavioral factors. This restriction improved the likelihood that any observed treatment disruption reflected a deviation from stable care, rather than initial treatment response variability. Cases on ART <6 months might be misclassified for example as being non-adherent, when in fact, they are just in the normal early treatment period, where viral rebound or missed visits can happen for physiological or adjustment reasons unrelated to water insecurity. This misclassification would occur regardless of exposure status, because both exposed (water insecure) and unexposed (water secure) participants in early ART phases could be wrongly classified as adherent or non-adherent. Such a misclassification could bias the results towards the null and lead to the underestimation of the true association between water insecurity and HIV treatment outcomes. Excluding those on treatment for less than 6 months was therefore methodologically sound as it helped make the analysis robust and results credible by ensuring that the outcome classification reflected true treatment interruptions and not the expected, early treatment phase variabilities.

i. Unlike objective 1 which employed mixed effects models, unconditional logistic regression was used for the case-control study to regress HIV treatment outcomes on water insecurity. A similar approach as in specific objective one was used, starting with univariate and then multivariable logistic regression where some covariates were adjusted

for. Conditional logistic regression, as is common for matched case-control studies, was not used for modelling because matching of cases and controls in this study was imperfect. Secondly, a multinomial regression that is common when there are several outcomes was not appropriate because the outcome for this study was a composite variable, since some constituent outcome variables like opportunistic infections had very few observations which would have destabilized models if modelled as separate outcomes. Odds ratios (ORs), adjusted odds ratios (AORs), 95% confidence intervals (CIs), and p-values were reported.

ii. Potential mediators, including ART adherence, mental health as determined by GAD-7 and PHQ-9 scores, and food insecurity, were measured but not adjusted for in the regression models, as they were conceptualized as causal intermediates on the pathway between water insecurity and HIV treatment outcomes. Since the objective was to estimate the total association, a mediation analysis with those mediators was not conducted to estimate a direct effect because estimating the direct effect would have required a formal mediation analysis and stronger assumptions than the study design (case-control) could support. Instead, they were measured to support interpretation of the primary association (total effect) by documenting plausible pathways through which water insecurity could impact HIV treatment outcomes. Basically, they were measured to explain, and not to adjust, the association.

iv. To test the hypothesis that sex does not modify the association between water insecurity and HIV outcomes in specific objective three, a test of interaction was used to test sex as an effect modifier. To do that, an interaction term was built by multiplying the exposure (binary water insecurity) by the potential effect modifier (sex) and modelling it using unconditional logistic regression model to assess differences in outcome between men and women who are water insecure. All interaction cells were checked to verify that each included at least 10 observations to ensure estimations of interaction were robust. A significant p-value for the interaction term at ($p<0.05$) would indicate that the association between water insecurity and HIV treatment outcomes was different for male and female participants.

v. Sensitivity analyses were performed to test robustness of findings under alternative modelling assumptions, for example to decide whether to include or exclude certain adjustment variables in the multivariable regression models. Variables that returned a p-value < 0.2 in the case-control study were included in the multivariable regression models. Missingness across analytic variables was minimal (<1%), enabling complete-case analysis for the sample.

For both objectives 1 and 3, multicollinearity, assessed using the Variance Inflation Factor (VIF), was low, with all variance inflation factors below recommended thresholds (maximum VIF = 1.60). Model fit was assessed using the log likelihood and a global Wald χ^2 test comparing the fitted model to a null model with no covariates. The model fit was strong (Wald $\chi^2 = 67.43$, $p < 0.001$).

All analysis code written by the study statistician was independently reviewed and verified by the lead author to enhance reproducibility and transparency.

For all the statistical analyses, alpha values were set at 0.05 with a 95% confidence interval.

Table 3.5: Summary of methods, data tools/sources and analysis by study objective

Objective	Sampling design	Sample size	Tools/data source	Analysis
Quantitative: Analytic Cross-sectional To estimate the prevalence and characterize the socio-ecological drivers and dimensions of water insecurity among adults on ART in Kisumu County, Kenya.	• Systematic sampling from two sampling frames of males and females • Purposive sampling of household and communal water sources	• 434 adults on ART • 34 water samples	• Clinical registers (MoH 362) • HH Questionnaire • HWISE • Water samples	• Descriptive statistics: – Summary Statistics – Tables – Graphs • Bivariate analyses; • Multilevel mixed-effects regression; • Laboratory techniques
Qualitative: Cross-sectional To explore the lived experiences and pathways through which	• Age- and gender-stratified purposive sampling	• 7 FGDs (46 adults on ART) 21 IDI participants	• FGD guide • IDI guide	• Thematic analysis using Dedoose: – Integrated inductive–deductive approach

water insecurity may impede successful HIV health outcomes				• Framework analysis
Quantitative: Case-control To measure the association of water insecurity with HIV health outcomes among adults on ART in Kisumu County and assess whether gender modifies the association	• Random sample of cases • Random sampling of controls at baseline	• 356 adults on ART: • 181 cases • 175 controls 'matched' 1:1	• Clinical registers • Household questionnaire • IWISE • Additional HIV treatment outcomes questionnaire • HFIAS	• Unconditional multiple regression • Effect modification analysis using tests of interaction

3.9 Ethical Considerations

i. Ethical clearance was obtained from Maseno University Scientific and Ethics Review Committee (MUSERC). A license to collect data was obtained from the National commission for science, technology, and innovation (NACOSTI) and permission to collect patient information from participating sites was obtained from the Kisumu County Government department of health.

ii. Written informed consent was obtained from all respondents to ensure potential participants were comprehensively provided with all information they required, in a language they understood, to voluntarily decide whether to participate in the study or not; and that they clearly understood the risks and benefits associated with their participation (ICF – appendix III).

Informed consent for participants below the age of 18 **was obtained from their respective legally authorized representatives (LAR) like parents or guardians**. Underage participants (15-17 years) had the ICF read out to them first, and if they were willing to participate, they gave assent by signing the form. Afterward, the same ICF was administered to the LAR, replacing 'you' with 'your child'. If the LAR was agreeable, he/she gave informed consent to participate by signing below the participant's assent signature.

For participants who could not read or write, the ICF was read out to them, after which they were provided with a stamp pad to put their thumbprints in lieu of signature where necessary. All signatures and thumbprints were accompanied by the respective dates. Each participant remained with a copy of ICF signed by the participant and the research assistant.

iii. Any study participant who responded YES to "having suicidal thoughts in the depression assessment was given a referral immediately after the interview to their respective facility in-charge for follow-up evaluation and assistance.

iv. Confidentiality of data, privacy of participants, and voluntary participation were guaranteed, including the freedom to withdraw from the study at any point and freedom not to respond to any question. All interviews were conducted privately. Interviewers were provided with sham questions to revert to in case of intrusion during the interviews. Completed digital tools were synchronized to a remote server in a password protected computer with restricted access. Interview notes were digitized and together with electronic data, saved in the same password protected computer, backed up in a cloud server then deleted from the electronic recorders. Data were not to be deleted for at least 10 years due to reproducibility requirements.

v. The study had minimal risks and direct benefits to participants. The reasonably foreseeable risks – such as the possibility of someone finding out that they were participating in a study were explained to the participants during the administration of the informed consent. Prospective participants were provided with information on whom to contact if they had questions, concerns, or complaints of harm or injury arising from their participation in the study. Additionally, they were provided with contact information of whom to contact if they needed to report any study-related infringements on their rights as individuals.

vi. To ensure justice, all participants had fair and equal chances of participating in the study. A representative study sample was selected randomly from all the study sites. Male and female participants were recruited proportionately, and no one was disadvantaged unfairly.

vii. All participant, location data, and any identifiable clinical information were de-deidentified using computer-generated unique study IDs to ensure anonymity and mitigate potential risks to participants, including physical, psychological, social, and economic harm.

viii. All study staff undertook mandatory training and got certification on Research Ethics in human subjects research prior to data collection.

ix. There were no conflicts of interest to be declared in this study. The study was funded by the SD4H program, a collaboration between Maseno University, KEMRI, and the University of California, San Francisco. However, the conceptualization and conduct of the study was wholly by the researcher. All data were primary, collected after ethical approval by MUSERC.

Ethical dilemma:

In a few cases, spouses of respondents insisted on being present during interviews, which went against the principle of respect for persons (autonomy). In one case, the respondent, a female, was clearly terrified in the presence of her husband, and the interview did not proceed at that time. Later, it turned out she had been widowed after her first marriage, and the current spouse was unaware of her HIV status. The dilemma was whether to protect her privacy, or inform the husband of the risk of HIV infection.

3.10 Dissemination of research findings

Findings from this study have been disseminated through several channels to ensure that the knowledge generated contributes to research, policy, and practice. Preliminary findings have been published in two peer-reviewed journals and through presentation at two international conferences (INTEREST 2026 in May in Tanzania, and AIDS 2026 in July in Brazil), and more will also be published in journals focusing on public health, HIV research, and water.

At the policy and community levels, the findings were to be shared with relevant stakeholders including the Kisumu County Departments of Health and Water & Sanitation, local health facilities, and organizations working with adults on ART in Kisumu County. Policy briefs were to be prepared to communicate key findings and recommendations to decision-makers.

CHAPTER FOUR: RESULTS & FINDINGS

This chapter presents the study findings. The results presented here are derived from the original analyses conducted as part of this doctoral research.

The results are organized following the logic of the specific objectives of the study which were:

i. To estimate the prevalence and characterize the socio-ecological drivers and dimensions of water insecurity among adults on ART in Kisumu County.
ii. To explore the lived experiences and pathways through which water insecurity may impede successful HIV treatment outcomes among adults on ART in Kisumu County.
iii. To determine the association of water insecurity with HIV treatment outcomes among adults on ART in Kisumu County, and whether sex modifies the association

Quantitative findings are explained in detail and presented using respective tables and figures, while qualitative findings are presented in narrative form with accompanying verbatim quotes. The second part of the qualitative study also has a table and a novel conceptual model developed from the results of the first part of the same study, and integrates the socio-ecological model.
Across the study phases, quantitative and qualitative findings are triangulated to examine areas where results converge, complement, expand upon, or diverge from one another.

4.1 Participant Baseline Sociodemographic characteristics

Elements of these findings have been disseminated in peer-reviewed publications (Odak, Murnane, et al., 2026). Where overlap exists, the published work is based on the analyses first undertaken for this thesis.

Among 443 randomly sampled adults on ART, 434 (98%) were interviewed and sociodemographic data analyzed for 433 comprising 142 males and 291 females (Table 1). The findings show the socio-demographic and household characteristics of the participants, disaggregated by sex. The median age overall was 44.0 years (IQR: 36.0–52.0). Most participants (81.5%) were aged 35 years and older, but there were no meaningful differences in age by sex. The majority of participants (56.9%) were currently married followed by the widowed category (28.8%), and almost all the widowed participants were female. There were differences in marital status by sex: while 83.8% of men were currently married, 41.9% of women were widowed and these differences

were significant. The median household size was 5.0 (IQR: 4.0–7.0), with almost half of the households (47.7%) having three to five members. There were differences in household size by sex as a continuous variable, but not by categories. More than half of participants (55.3%) lived in semi-permanent housing, 34.8% in temporary structures, and only 9.9% in permanent housing but no notable differences by sex were observed based on housing type.

The majority of respondents (42.6%) completed primary education, 35.3% had no formal education, and a small proportion (8.3%) attained vocational training. That pattern was similar when comparing educational attainment between male and female participants though majority of female respondents had only completed primary education. In terms of employment, there were differences by sex. The results showed that 42.9% of all participants were self-employed, 37.6% were casual laborers, 15.2% were unemployed, and 4.4% were in salaried employment. Most females were either casual laborers (42.3%) or self-employed (41.2%), while among males, self-employment (46.5%) was most common.

Regarding income, 59.4% of all participants fell in the very low-income category (earning less than KES 5,000 per month), 23.0% were in the low-income category (KES 5,001–10,000), and 17.5% in the medium income category (above KES 10,000). Among females, 70.8% were in the very low-income group, compared to 36.6% of males; and the observed differences by sex were significant. Notably, there were differences in household water insecurity by sex. More female (75.6%) than male (41.5%) participants had water insecurity (water insecurity score ≥12 on HWISE 12 scale).

Table 4.1: Participant socio-demographic characteristics of adults on ART by sex (N=433)

Characteristic	Total	Male	Female	p-value
N	433	142	291	
Age, median (IQR)	44.0 (36.0, 52.0)	43.0 (37.0, 51.0)	44.0 (36.0, 52.0)	0.93
Age group				0.31
15-24	32 (7.6%)	12 (8.5%)	20 (6.9%)	
25-34	48 (11.1%)	11 (7.7%)	37 (12.7%)	
35-44	150 (34.6%)	55 (38.7%)	95 (32.6%)	
=>45	203 (46.8%)	64 (45.1%)	139 (47.8%)	
Marital status				**<0.001**
Never married	36 (8.3%)	12 (8.5%)	24 (8.2%)	
Currently married	246 (56.9%)	119 (83.8%)	127 (43.6%)	
Separated	26 (6.0%)	8 (5.6%)	18 (6.2%)	
Widowed	125 (28.8%)	3 (2.1%)	122 (41.9%)	
Household size, median (IQR)	5.0 (4.0, 7.0)	5.5 (4.0, 7.0)	5.0 (4.0, 6.0)	**0.009**
Household size categories				0.062
1-2	45 (10.4%)	12 (8.5%)	33 (11.3%)	
3-5	206 (47.7%)	59 (41.5%)	147 (50.5%)	
=>6	182 (41.9%)	71 (50.0%)	111 (38.1%)	
Type of housing				0.16
Temporary	151 (34.8%)	47 (33.1%)	104 (35.7%)	
Semi-permanent	240 (55.3%)	86 (60.6%)	154 (52.9%)	
Permanent	42 (9.9%)	9 (6.3%)	33 (11.3%)	
Level of education				**<0.001**
None	153 (35.3%)	29 (20.4%)	124 (42.6%)	
Primary complete	185 (42.6%)	51 (35.9%)	134 (46.0%)	
Secondary complete	59 (13.8%)	37 (26.1%)	22 (7.6%)	
Vocational training	36 (8.3%)	25 (17.6%)	11 (3.8%)	
Employment status				**<0.001**
Unemployed	66 (15.2%)	23 (16.2%)	43 (14.8%)	
Self-employed	186 (42.9%)	66 (46.5%)	120 (41.2%)	
Casual laborer	163 (37.6%)	40 (28.2%)	123 (42.3%)	
Employed -salaried	18 (4.4%)	13 (9.2%)	5 (1.7%)	
Income category				**<0.001**
Very low (<5000)	258 (59.4%)	52 (36.6%)	206 (70.8%)	
Low (5001-10000)	100 (23.0%)	33 (23.2%)	67 (23.0%)	
Medium (>10000)	75 (17.5%)	57 (40.1%)	18 (6.2%)	
Water security status				**<0.001**
Water secure	154 (35.7%)	83 (58.5%)	71 (24.4%)	
Water insecure	**279 (64.3%)**	59 (41.5%)	220 (75.6%)	

4.2 Prevalence and distribution of water insecurity

The analyses showed a 64.3% prevalence of water insecurity among adults on ART in the baseline study sample of 434 participants (Table 4.1). The HWISE mean water insecurity score was 16.1 with a standard deviation of 10.2. When examined within HWISE categories, 9.2% of the participants (n = 40) had no to marginal water insecurity scores; 26.5% (n = 115) had a low water insecurity score; 41.9% (n = 182) fell within the moderate water insecurity score category and 22.4% (n = 97) had high water insecurity scores (Figure 4.1a & b).

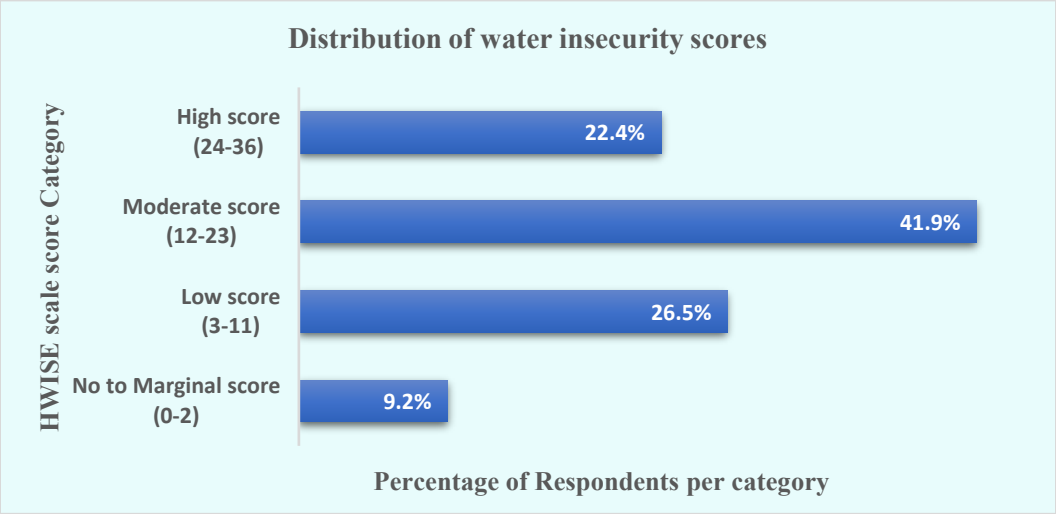


Figure 4.1 a): Household water insecurity by severity

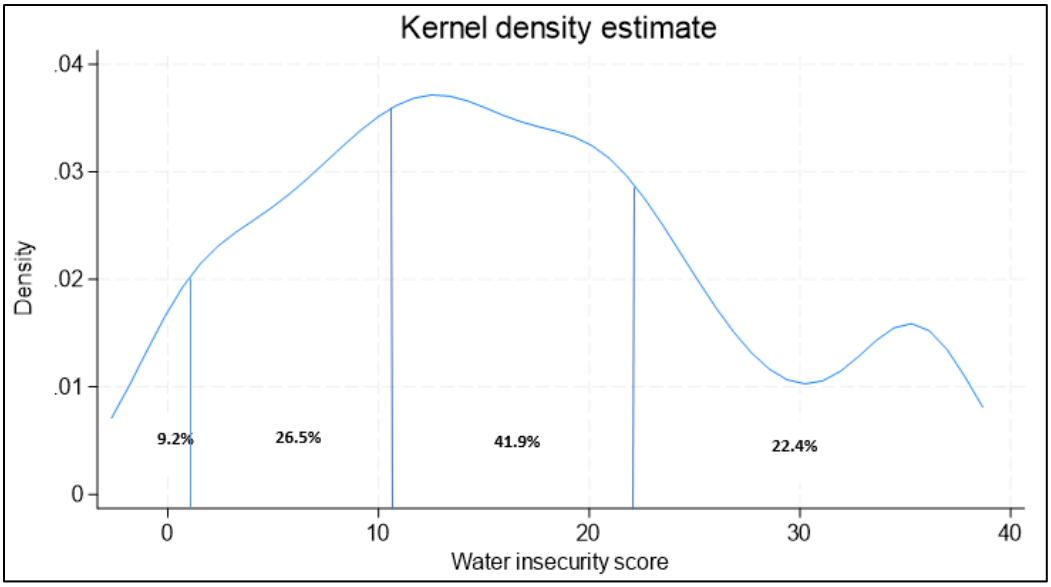


Figure 4.1 b): Kernel density plot of distribution of water insecurity scores

4.3 Socio-ecological drivers and dimensions of water insecurity

4.3.1 Perceived drivers of water insecurity

The results show that almost all respondents (96.8%) identified lack of rainfall or drought as a major driver of water insecurity, while 90.3% and 90.1% cited poverty and poor/lack of water supply infrastructure as major drivers of water insecurity respectively (Figure 4.2). Participants also reported broader effects of climate change (88.7%) and water scarcity or lack of natural water sources (84.1%) as important drivers, while flooding, reported by 82.9% of participants, also ranked high among the major drivers of water insecurity. More than four out of five participants (81.1%) indicated polluted and contaminated water sources, and 79.5% identified their geographic location and topography as distal drivers of water insecurity. Competition for available water due to a large population was also reported by 62.2% of participants as another cause of water insecurity. In contrast to these high proportions, only a minority (14.1%) of participants believed that conflicts and inter-tribal clashes were possible drivers of water insecurity in Kisumu County.

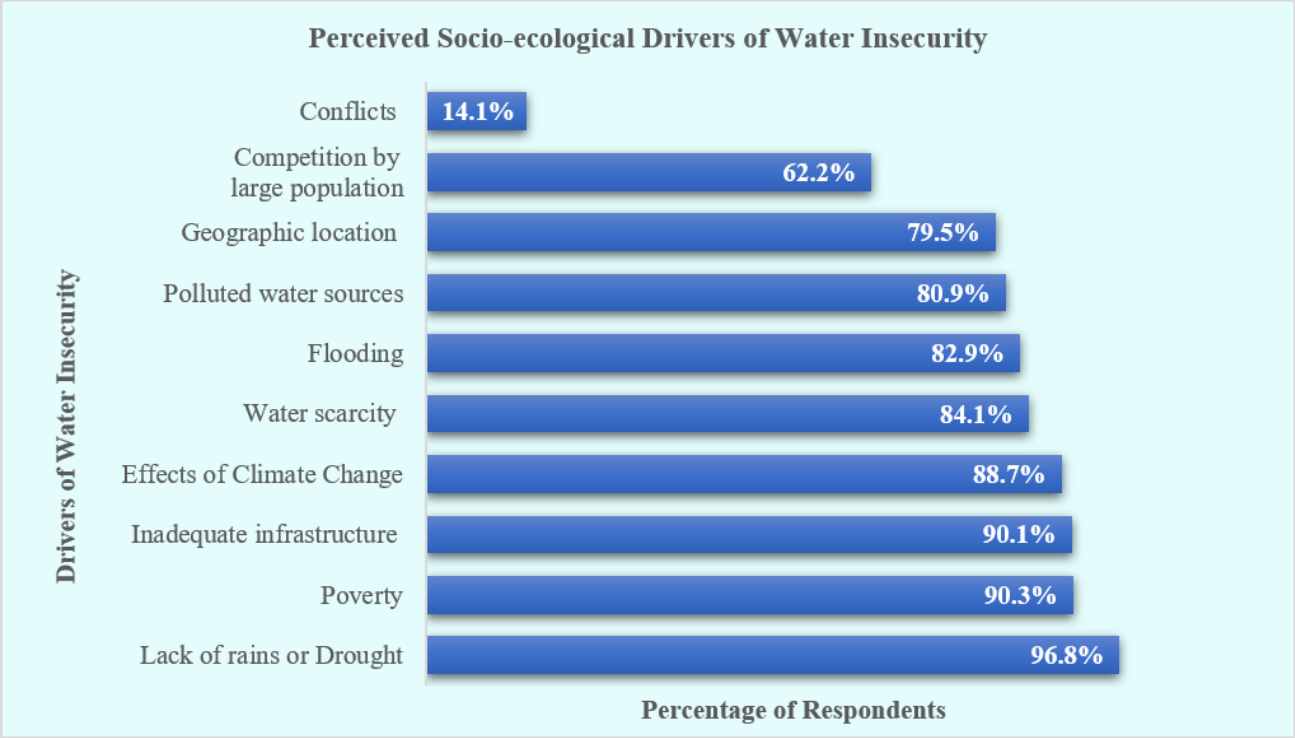


Figure 4.2: Perceived Socio-ecologic drivers of water insecurity

4.3.2 Perceived dimensions of water insecurity

Apart from measuring household water insecurity, perceived community-level dimensions of water insecurity among adults on ART were assessed, with a focus on availability (scarce or excessive availability), access (reliability, distance, time, storage and affordability of obtaining water), and quality (physical, chemical, and pathogenic contamination).

On water availability, 85.4% reported seasonal experience of excessive water availability due to flooding (Figure 4.3). In terms of ground water availability, 61.9% of participants reported that their area of residence had a low water table or had scant ground water availability, while 42.1% reported their challenge to be waterlogged land or high water tables. Only 11.3% reported they had enough water for farming.

Regarding community-level access, 71.1% of the participants reported they could not access enough water for domestic use, against 28.9% who could. Most participants (85.8%) lacked access to piped water connectivity, against 14.2% who had, and 82.4% struggled to afford or purchase the required water from available vending sources. Regarding physical access, 65.4% lived far from improved water sources. Unreliable access or seasonal water supply were reported by 34.6% of respondents; and only 13.4% had adequate water storage facilities to ensure household water access.

The quality dimension was measured in two ways: participant self-report and laboratory-based water quality testing. Based on self-reported water quality, 80.2% of participants pointed out visible physical contamination of water with soil, rubbish, and other materials from the surrounding environment. Three-quarters of participants (75.7%) reported that the water sources for their household use were contaminated with germs capable of causing illness. Less than half of the participants (43.8%) indicated that their sources were polluted with chemicals from industrial activities and vehicles. These concerns were corroborated by laboratory tests, which identified physicochemical and microbiological contamination in several household and communal water sources.

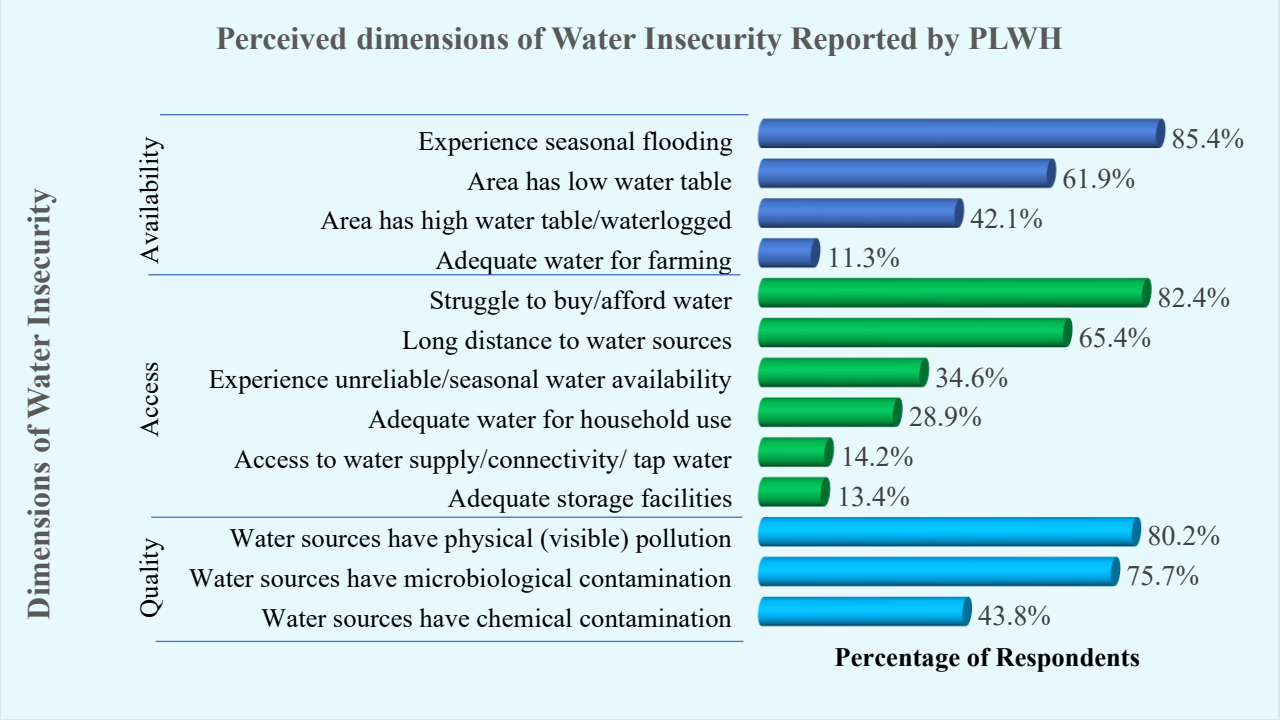


Figure 4.3: Perceived dimensions of water insecurity

4.3.3 Predictors of water insecurity among adults on ART

Next, multilevel mixed effects logistic regression models were used to identify sociodemographic and community-level characteristics that were independently associated with household water insecurity. Odds ratios (OR), adjusted odds ratios (AOR), 95% confidence intervals (CI), and p-values were reported.

4.3.3.1 Sociodemographic predictors of water insecurity

At the individual and interpersonal levels of the SEM, several sociodemographic characteristics had significant associations with water insecurity in both univariate and multivariable analyses (Table 4.2). Younger age was initially protective, with participants aged 15–24 years having 66% lower odds of water insecurity (OR = 0.34, 95% CI: 0.16–0.75, p = 0.007) compared to those over 45 years, though the association was attenuated after adjustment (AOR = 0.22; 95% CI: 0.02–2.31; p = 0.207). Other age groups were not significantly associated with water insecurity overall, with no significant differences observed for older age groups, compared to the reference group, even after adjusting for other covariates. Sex was an independent predictor of water insecurity.

Being female was associated with almost five times the odds of being water insecure in unadjusted (OR = 4.88; 95% CI: 3.11–7.67; p < 0.001), and almost four times the odds of being water insecure in adjusted models (AOR = 3.65; 95% CI: 2.02–6.58; p < 0.001), compared to being male. In post-hoc analyses, the marginal predicted probability of being water insecure for women was 72.9% (95% CI: 67.5–78.2) and 48.3% (95% CI: 39.3–57.3) for men. Household size did not reach statistical significance in univariate analysis (OR = 1.08; 95% CI: 0.98–1.18; p = 0.130). After adjustment, the effect size increased, whereby each additional household member was associated with 23% higher odds of water insecurity (AOR = 1.23; 95% CI: 1.09–1.39; p = 0.001).

Marital status was significantly associated with water insecurity only among widowed participants, who had 2.5 times the odds of water insecurity in unadjusted analysis (OR = 2.46; 95% CI: 1.48–4.08; p <0.001), compared to married participants. However, the association, though showing almost two times the odds of water insecurity, was not maintained after adjustment (AOR = 1.98; 95% CI: 0.97–4.07; p = 0.062).

Higher educational attainment showed protective effects in the unadjusted model. Compared to no education, attainment of primary education had no significant association with water insecurity in both unadjusted and adjusted analyses. Participants with secondary education had 65% lower odds of water insecurity in unadjusted analysis (OR = 0.35, 95% CI: 0.18–0.66, p = 0.001), although this association did not reach statistical significance after adjustment (AOR = 1.27; 95% CI: 0.57–2.83; p = 0.562). Those with vocational training had 82% lower odds of water insecurity in unadjusted analysis (OR = 0.18, 95% CI: 0.08–0.40, p < 0.001), but this association was also attenuated and not significant after adjustment (AOR = 0.55; 95% CI: 0.20–1.53; p = 0.252).

On employment status, casual laborers had higher odds of water insecurity compared to the self-employed before adjustment (OR = 1.68; 95% CI: 1.03–2.74; p = 0.036), but the association did not reach statistical significance after adjusting for other covariates. No significant associations were found for unemployed participants in both unadjusted and adjusted analyses.

Housing type showed a strong association with water insecurity. Compared to living in semi-permanent housing, living in temporary housing was associated with over three times the odds of water insecurity in unadjusted analysis (OR = 3.11; 95% CI: 1.86–5.20; p <0.001), and remained significant after adjustment (AOR = 3.10; 95% CI: 1.75–5.51; p < 0.001). Living in permanent housing, though not statistically significant, had a protective effect with 32% (OR = 0.68; 95% CI:

0.35–1.31; p = 0.246), and 48% (AOR = 0.52; 95% CI: 0.24–1.12; p < 0.095) lower odds of water insecurity, compared to living in semi-permanent housing.

Income category was also associated with water insecurity. Compared to households with very low monthly income (<KSh 5,000), participants with low income (KSh 5,001–10,000) had lower odds of water insecurity in unadjusted analysis (OR = 0.57; 95% CI: 0.34–0.95; p = 0.031), but this was not significant after adjustment (AOR = 0.61; 95% CI: 0.33–1.11; p = 0.104). Those in the medium income category (>KSh 10,000) had 80% lower odds of water insecurity in unadjusted (OR = 0.20; 95% CI: 0.11–0.36; p < 0.001) and 55% lower odds of water insecurity in adjusted models (AOR = 0.45; 95% CI: 0.20–0.97; p = 0.042)), compared to very low monthly income.

Table 4.2: Socio-demographic predictors of water insecurity

Predictor	n (%) / Median (IQR)	Univariate OR (95% CI)	p-value	Multivariable AOR (95% CI)	p-value
Age: Median (IQR)	44.0 (36.0, 52.0)	1.01 (1.00–1.03)	0.156		
Age categories: n (%)					
>45	203 (46.8%)	Ref			
15–24	33 (7.6%)	0.34 (0.16–0.75)	**0.007**	0.22 (0.02-2.31)	0.207
25–34	48 (11.1%)	1.25 (0.62–2.51)	0.529	0.87 (0.22-3.44)	0.847
35–44	150 (34.6%)	0.88 (0.56–1.39)	0.578	0.83 (0.36-1.92)	0.664
Sex: n (%)					
Male	142 (32.8%)	Ref			
Female	291 (67.2%)	4.88 (3.11–7.67)	**<0.001**	3.65 (2.02-6.58)	**<0.001**
HH Size: Median (IQR)	5.0 (4.0, 7.0)	1.08 (0.98–1.18)	0.130	1.23 (1.09-1.39)	**0.001**
Education Level: n (%)					
No education	153 (35.3%)	Ref			
Primary	185 (42.6%)	0.74 (0.46–1.20)	0.227	0.93 (0.53-1.61)	0.788
Secondary complete	60 (13.8%)	0.35 (0.18–0.66)	**0.001**	1.27 (0.57-2.83)	0.562
Vocational training	36 (8.3%)	0.18 (0.08–0.40)	**<0.001**	0.55 (0.20-1.53)	0.252
Marital Status: n (%)					
Currently Married	247 (56.9%)	Ref			
Never married	36 (8.3%)	0.55 (0.26–1.13)	0.101	0.63 (0.17-2.35)	0.491
Separated	26 (6.0%)	1.28 (0.55–3.00)	0.564	1.20 (0.44-3.25)	0.725
Widowed	125 (28.8%)	2.46 (1.48–4.08)	**<0.001**	1.98 (0.97-4.07)	0.062
Employment status: n (%)					
Self employed	186 (42.9%)	Ref			
Unemployed	66 (15.2%)	1.08 (0.60–1.95)	0.794	1.75 (0.72-4.24)	0.216
Casual laborer	163 (37.6%)	1.68 (1.03–2.74)	**0.036**	1.51 (0.86-2.66)	0.148
Employed (salary)	19 (4.4%)	0.69 (0.26–1.79)	0.442	2.28 (0.66-7.86)	0.193
Type of housing n (%)					
Semi-permanent	240 (55.3%)	Ref			
Temporary housing	151 (34.8%)	3.11 (1.86–5.20)	**<0.001**	3.10 (1.75-5.51)	**<0.001**
Permanent housing	43 (9.9%)	0.68 (0.35–1.31)	0.246	0.52 (0.24-1.12)	0.095
Income categories n (%)					
Very low <5,000	258 (59.4%)	Ref			
Low (5,001–10,000)	100 (23.0%)	0.57 (0.34–0.95)	**0.031**	0.61 (0.33-1.11)	0.104
Medium (>10,000)	76 (17.5%)	0.20 (0.11–0.36)	**<0.001**	0.45 (0.20-0.97)	**0.042**

4.3.3.2 Community-level predictors of water insecurity

Consistent with the SEM, an assessment was done to determine which community-level factors related to water availability, access, and quality predicted household water insecurity. In unadjusted models, low water table (OR = 4.77, 95% CI: 1.88–12.14, p = 0.001) and high water table (OR = 5.37, 95% CI: 2.14–13.48, p <0.001), compared to normal water table, were associated with higher odds of water insecurity, but were non-significant after adjustment (Table 4.3). Long distance to water sources was significantly associated with greater odds of water insecurity in both unadjusted (OR = 3.44, 95% CI: 2.17–5.47, p < 0.001) and adjusted (AOR = 2.10, 95% CI: 1.27–3.48, p = 0.004) analyses. Water sources with chemical pollution were significantly associated with greater odds of water insecurity in unadjusted (OR = 5.72, 95% CI: 3.49–9.38, p < 0.001) and adjusted (AOR = 2.70, 95% CI: 1.54–4.72, p = 0.001) analyses. Similarly, sources with microbial contamination were significantly associated with water insecurity in unadjusted (OR = 10.04, 95% CI: 5.94–16.95, p < 0.001) analyses and remained an independent predictor after adjustment (AOR = 3.96, 95% CI: 2.07–7.59, p < 0.001). Physical pollution was also strongly associated with water insecurity in unadjusted analyses (OR = 5.78, 95% CI: 3.34–10.01, p < 0.001).

Table 4.3: Community-level predictors of water insecurity

Predictor	n (%)	OR (95% CI)	p-value	AOR (95% CI)	p-value
Excessive water / flooding					
No	62 (14.6%)	Ref			
Yes	363 (85.4%)	1.56 (0.86–2.85)	0.147	1.40 (0.72–2.74)	0.318
Water table					
Very low	27 (6.4%)	Ref			
Low	157 (36.9%)	4.77 (1.88–12.14)	**0.001**	1.49 (0.51–4.37)	0.465
High	241 (56.7%)	5.37 (2.14–13.48)	**<0.001**	1.94 (0.67–5.61)	0.221
Long distance to sources					
No	147 (34.6%)	Ref			
Yes	278 (65.4%)	3.44 (2.17–5.47)	**<0.001**	2.10 (1.27–3.48)	**0.004**
Unreliable/seasonal availability					
No	278 (65.4%)	Ref			
Yes	147 (34.6%)	1.02 (0.64–1.62)	0.942		
Water source polluted (Chemical)					
No	239 (56.2%)	Ref			
Yes	186 (43.8%)	5.72 (3.49–9.38)	**<0.001**	2.70 (1.54–4.72)	**0.001**
Water source contaminated with germs (Biological)					
No	103 (24.3%)	Ref			
Yes	321 (75.7%)	10.04 (5.94–16.95)	**<0.001**	3.96 (2.07–7.59)	**<0.001**
Water source dirty (Physical)					
No	84 (19.8%)	Ref			
Yes	341 (80.2%)	5.78 (3.34–10.01)	**<0.001**	1.76 (0.90–3.43)	0.098

From the preceding table (4.3), the associations of other water-related ecologic dimensions with water insecurity, including water table and physical pollution of sources were attenuated and no longer statistically significant in adjusted models.

4.3.4 Microbiological and physicochemical water quality

Water quality, with regards to biological, physical, and chemical safety was established by collecting and testing 34 water samples from household and communal water sources reported by participants. The laboratory test results showed the microbiological and physicochemical quality of the water from the sources. Overall, the results indicated widespread microbial contamination and several physicochemical exceedances of recommended WHO and KEBS limits, suggesting that many of the water sources used by study participants were not safe for direct consumption at the time of sampling.

Distribution of sampled water sources

Surface water sources constituted the largest proportion of sampled water points, reflecting their importance as accessible water sources for households. Groundwater sources, including boreholes and wells, were also widely used. Rainwater harvesting systems were less common but were present in several households.

Table 4.4: Distribution of sampled water sources by source type

Water source category	Source types included	Number of samples
Surface water	Rivers, streams, ponds, lake water	19
Groundwater	Boreholes, protected wells, shallow wells, springs	11
Rainwater/storage	Rainwater harvesting and tank water	3
Piped/project supply	Community water project tap	1
Total		**34**

4.3.4.1 Microbiological Quality of Water Sources

Microbiological analysis assessed the presence of total coliforms and E. coli as indicators of microbial contamination. According to WHO drinking water guidelines, potable water should contain 0 CFU/100 mL of total coliforms and E. coli.

Microbiological contamination was widespread across the sampled water sources. E. coli, indicating fecal contamination, was detected in 12 of the 34 samples (35.3%), while an additional 14 samples (41.2%) contained total coliform bacteria but no detectable E. Coli (Table 4.5). Only eight sources (23.5%) showed no detectable coliform bacteria.

Table 4.5: Microbiological classification of water samples from sources used by adults on ART (n = 34)

Microbiological classification	Number of samples	(%)
E. coli detected	12	35.3
Total coliforms detected (no E. coli)	14	41.2
No coliforms detected	8	23.5
Total	**34**	**100**

*E. coli indicates fecal contamination, while total coliforms indicate possible environmental or fecal contamination

Surface water sources

A total of 19 samples were collected from surface water sources, including rivers, streams, ponds, lake water points, and irrigation channels. Among these samples, E. coli was detected in 7 (36.8%), while 12 samples (63.2%) contained total coliform bacteria without detectable E. coli. The median E. coli concentration was 0 CFU/100 mL, with a range of 0–4000 CFU/100 mL. Total coliform concentrations in surface water sources had a median value of 2000 CFU/100 mL, with observed values ranging from 100 to 12000 CFU/100 mL.

Groundwater sources

A total of 11 samples were obtained from groundwater sources, including boreholes, protected wells, shallow wells, and natural groundwater springs locally referred to as soko. Among these samples, E. coli was detected in 4 (36.4%), while 2 samples (18.2%) contained total coliform bacteria without detectable E. coli. The remaining five groundwater samples showed no detectable coliform bacteria. The median E. coli concentration was 0 CFU/100 mL, with a range of 0–2000 CFU/100 mL. Total coliform concentrations had a median of 100 CFU/100 mL, with a range of 0–3000 CFU/100 mL.

Rainwater tanks

Three samples were collected from rainwater harvesting and tank storage systems. E. coli was detected in one sample (33.3%), while the remaining two samples showed no detectable E. coli. Total coliform concentrations in this category had a median of 0 CFU/100 mL, with observed

values ranging from 0 to 18000 CFU/100 mL. The median E. coli concentration was 0 CFU/100 mL, with a range of 0–5000 CFU/100 mL.

Piped water supply

One sample was collected from a community piped water source associated with the Sondu Miriu Hydroelectric Power Project. In this sample, no total coliform bacteria or E. coli were detected, with both indicators recorded as 0 CFU/100 mL.

Table 4.6: Descriptive analysis of microbiological contamination of sampled water sources by source category

Water source		E.coli				Total Coliforms (TC)			
Category	**N**	**E. coli detected (n)**	**E. coli (%)**	**Median E. coli (CFU/100 mL)**	**Range E. coli**	**TC only (n)**	**TC (%)**	**Median TC (CFU/100 mL)**	**Range TC**
Surface water	19	7	36.8	0	0–4000	12	63.2	2000	100–12000
Groundwater	11	4	36.4	0	0–2000	2	18.2	100	0–3000
Rainwater/storage	3	1	33.3	0	0–5000	0	0	0	0–18000
Piped/project supply	1	0	0	0	0–0	0	0	0	0–0
Total	**34**	**12**	**35.3**			**14**			

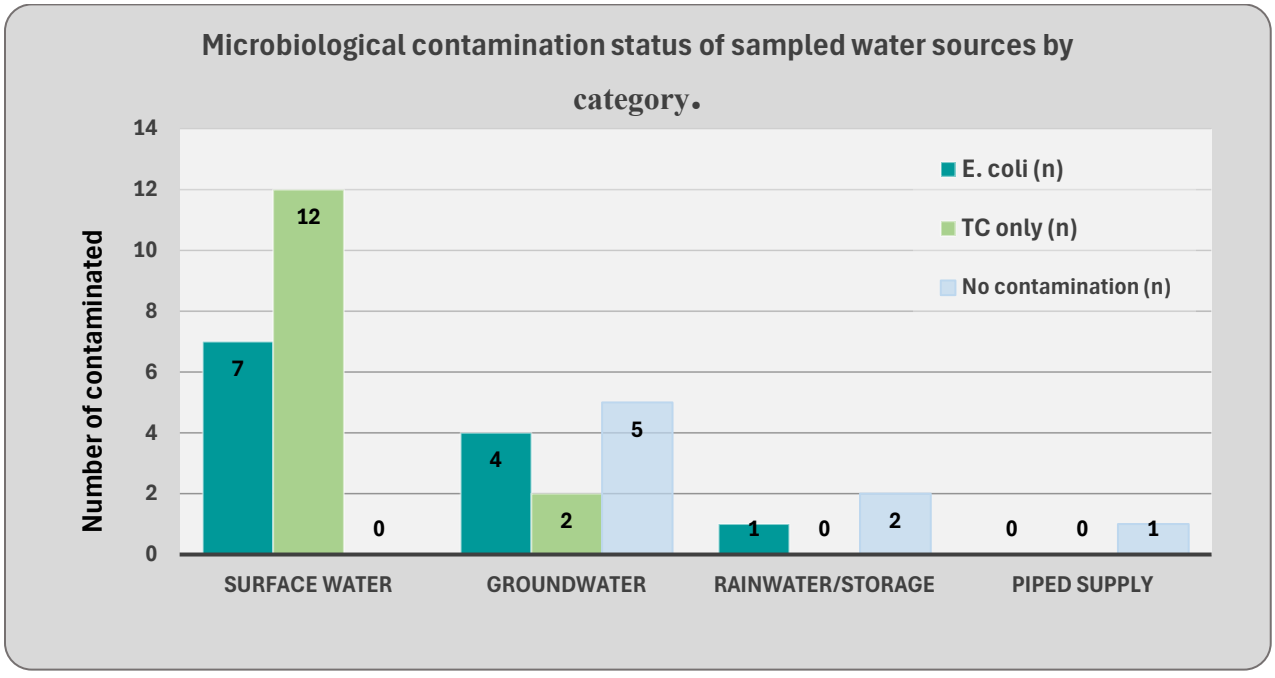


Figure 4.4: Number of contaminated water sources by source category and contamination type

4.3.4.2 Physical and chemical quality water sources used by adults on ART

Physicochemical analysis evaluated key parameters related to water chemistry, mineral content, and potential toxic elements. These values were compared with WHO guideline limits for drinking water quality. Although the most commonly reported parameters for drinking water quality include basic indicators such as pH, total dissolved solids (TDS), and major mineral ions, the present study assessed a broader set of 23 physicochemical parameters to comprehensively characterize the quality of water sources commonly used by adults on ART in the study area. These parameters included basic water properties, major ions, nutrients, and trace metals. The observed values and the number of samples exceeding recommended drinking water guideline values are presented in Table 4.7.

Across the sampled water sources, measured pH values ranged from 5.01 to 9.12, with 15 of the 34 samples (44.1%) falling outside the recommended range of 6.5–8.5. Electrical conductivity varied substantially among samples, ranging from 6 to 2681 µS/cm, with 9 samples (26.5%) exceeding the recommended limit of 800 µS/cm. Total dissolved solids ranged from 3 to 1340 mg/L, and none of the samples exceeded the guideline value of 2000 mg/L. Turbidity showed the greatest variability among the basic water quality indicators, ranging from 0.25 to 449 NTU, with 22 samples (64.7%) exceeding the recommended limit of 5 NTU.

Among the major ions, calcium, magnesium, chloride, and sulfate concentrations remained within recommended limits in all samples. Sodium concentrations ranged from 2.7 to 257 mg/L, with one sample exceeding the recommended limit of 200 mg/L, while potassium ranged from 0.69 to 95.7 mg/L, with four samples (11.8%) exceeding the recommended limit of 50 mg/L. Bicarbonate concentrations ranged from 27.45 to 924.15 mg/L, with 19 samples (55.9%) exceeding the recommended limit of 150 mg/L.

For nutrient-related parameters, nitrate concentrations ranged from 1.12 to 33.6 mg/L, with four samples (11.8%) exceeding the recommended limit of 10 mg/L. Ammonium concentrations ranged from 1.12 to 22.7 mg/L, with eight samples (23.5%) exceeding the recommended limit of 3 mg/L, while phosphate concentrations ranged from 0.10 to 2.54 mg/L, remaining below the recommended limit in all samples.

Trace metal concentrations varied across the sampled water sources. Iron concentrations ranged from 0.01 to 47.6 mg/L, with 14 samples (41.2%) exceeding the recommended limit of 0.3 mg/L.

Manganese concentrations ranged from not detected (ND) to 1 mg/L, with 11 samples (32.4%) exceeding the recommended limit of 0.1 mg/L. Aluminum concentrations ranged from 0.01 to 40.7 mg/L, with 17 samples (50.0%) exceeding the recommended limit of 0.2 mg/L. Zinc, copper, cadmium, lead, and boron concentrations were detected at low levels across the samples and had no exceedances.

Table 4.7: Physicochemical characteristics of sampled water sources and guideline exceedances (n = 34)

Parameter	Guideline value	Observed range	Samples exceeding (n)	%
Basic water properties				
pH	6.5–8.5	5.01–9.12	15	44.1
Electrical Conductivity (µS/cm)	≤ 800	6–2681	9	26.5
Total Dissolved Solids (mg/L)	≤ 2000	3–1340	0	0
Turbidity (NTU)	≤ 5	0.25–449	22	64.7
Major ions				
Calcium (mg/L)	≤ 150	0.54–124	0	0
Magnesium (mg/L)	≤ 100	0.23–40.7	0	0
Sodium (mg/L)	≤ 200	2.7–257	1	2.9
Potassium (mg/L)	≤ 50	0.69–95.7	4	11.8
Bicarbonate (mg/L)	≤ 150	27.45–924.15	19	55.9
Chloride (mg/L)	≤ 250	2.13–67.45	0	0
Sulfate (mg/L)	≤ 400	2.43–286	0	0
Nutrients				
Nitrate (mg/L)	≤ 10	1.12–33.6	4	11.8
Ammonium (mg/L)	≤ 3	1.12–22.7	8	23.5
Phosphate (mg/L)	≤ 30	0.10–2.54	0	0
Trace metals				
Iron (mg/L)	≤ 0.3	0.01–47.6	14	41.2
Manganese (mg/L)	≤ 0.1	ND–1	11	32.4
Aluminum (mg/L)	≤ 0.2	0.01–40.7	17	50.0
Zinc (mg/L)	≤ 5	0.001–2.44	0	0
Copper (mg/L)	≤ 1	0.001–0.10	0	0
Cadmium (mg/L)	≤ 0.5	ND–0.23	0	0
Lead (mg/L)	≤ 0.01	ND–0.01	0	0
Boron (mg/L)	≤ 1	0.001–0.05	0	0

- **ND = Not detected**
- **Guideline values based on recommended drinking water standards.**

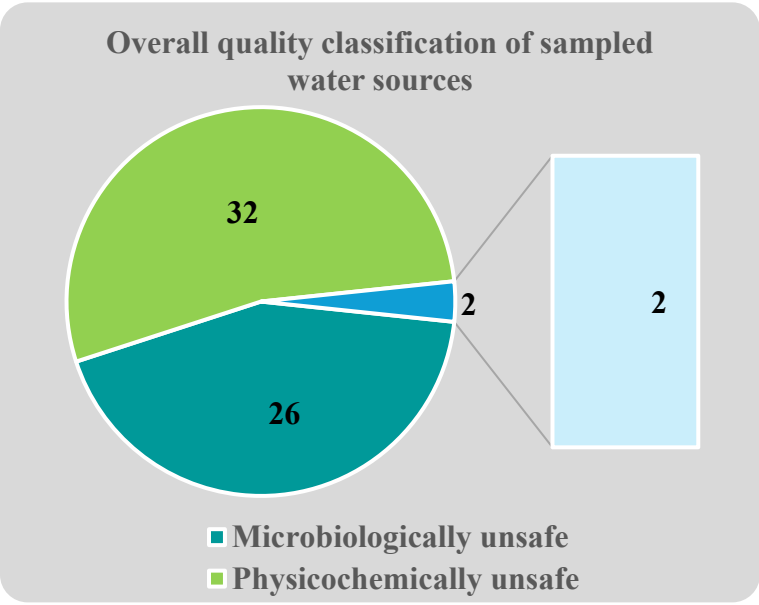
The preceding table shows the 22 out of 23 physical and chemical properties that were tested. Total suspended solids were measured but was undetected in all 34 samples, therefore left out of the table.

Table 4.8: Selected physicochemical parameters of sampled water sources compared with guideline limits

Parameter	WHO guideline	Observed range
pH	6.5–8.5	**5.01–9.12**
Conductivity (µS/cm)	≤800	**6–2681**
Total Dissolved Solids (mg/L)	≤2000	3–1340
Chloride (mg/L)	≤250	**2.13–67.45**
Nitrate (mg/L)	≤10	**1.12–33.6**
Iron (mg/L)	≤0.3	**0.01–47.6**
Manganese (mg/L)	≤0.1	**ND–1**
Lead (mg/L)	≤0.01	ND–0.01
Turbidity (NTU)	≤5	**0.25–449**

Turbidity, bicarbonate, aluminum, iron, and manganese were among the parameters most frequently exceeding recommended guidelines.

4.3.4.3 Summary of water quality analysis from sampled sources used by adults on ART i



Overall, the water quality analysis revealed widespread microbial contamination and physicochemical exceedances across the sampled water sources. Of the 34 samples, 26 had microbiological contamination and 32 had physicochemical contamination, and only two samples met the recommended safety standards (Figure 4.5a).

Figure 4.5 a): Overall contamination by quality classification

The overlap between microbiologically safe and physicochemically compliant water sources is shown in Figure 4.5b. Six water sources that appeared microbiologically safe failed to meet physicochemical standards, while the one source that met physicochemical guidelines was microbiologically contaminated. Only two water sources: piped water and water from one rainwater storage tank met both microbiological & physicochemical drinking water standards.

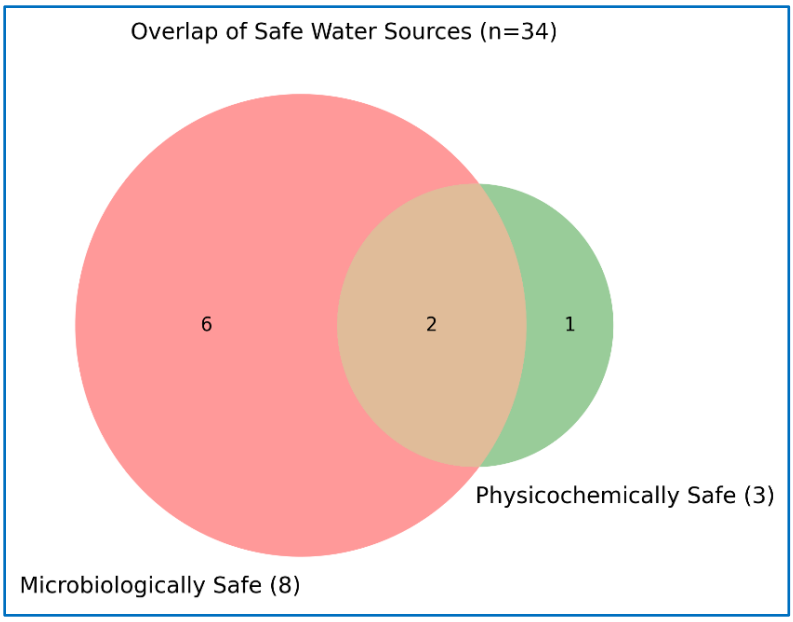


Figure 4.5b): Overlap between microbiologically and physicochemically safe sources

These laboratory findings corroborate and extend the cross-sectional and qualitative findings on water contamination by providing objective lab-based evidence of perceived water quality risks reported by participants.

4.4 The lived experience of water insecurity and pathways to HIV treatment outcomes

This section presents results from the qualitative study on the lived experience of water insecurity among adults on ART in Kisumu County as emergent from the thematic analysis of the data, and pathways from water insecurity to HIV treatment outcomes. The findings elucidate how challenges in accessing safe and reliable water affect the daily life, health, and HIV treatment outcomes among adults on ART, with participant voices showing how the experience of water insecurity affect adults on ART such that their physical and mental well-being; and their ability to engage productively in social and cultural activities is compromised. This limited ability aligns with the capability framework which explains how capability constraints limit the functionings that adults on ART can achieve, for example, maintaining physical health, managing household roles, or participating meaningfully in community life activities.

4.4.1 The lived experience of water insecurity among adults on ART in Kisumu County

Eight main themes emerged from the analysis, each illustrated with participant quotes and several supported by quantitative evidence from the baseline cross-sectional and case-control studies. The themes are numbered using 1), 2), …8); while the sub-themes are numbered as a), b), c).

1) Adults on ART in Kisumu County grapple with environmental factors that predispose and increase their vulnerability to water insecurity

Environmental conditions such as geography, climate variability, and extreme weather events shape water availability, access, and quality, predisposing adults on ART to persistent water insecurity.

a) Proximity to large bodies of surface water predisposes participants to effects of flooding

Geographically, the study area borders Lake Victoria, along the shores of two large rivers. One of the study sites is on the plains, characterized by soils with poor porosity, and is prone to flooding from increased precipitation, back-flow from the lake and when the main river bursts its banks.

> *"For me, staying close to the river causes flooding, which damages my house and property and kills my chickens. I have been displaced because of flooding that even caused the house to collapse, and I had to seek accommodation elsewhere because it was no longer safe to remain in my home." [IDI _AS058, female; age 40]*

> *"When River Nyando burst its banks due to heavy rains, the overflow water floods farms..." [IDI _AS044, female; age 52]*

b) Extreme and unpredictable weather contributes to water insecurity

Participants consistently linked their water insecurity to extreme and increasingly unpredictable weather patterns, describing prolonged dry seasons followed by unusually intense rainfall. These shifts were reported to disrupt water availability and quality, resulting in alternating periods of severe scarcity and excessive water that contaminated available sources.

> *"Weather and climate change contribute significantly to the water insecurity challenge we face; in December (2024), there were extremely heavy rains that we do not expect at that time, that damaged crops. Now we are in the dry season, so there will be a water shortage. During the dry season these days, it is too dry for too long, making the water insecurity problem worse." [FGD_CS, female; age35-44]*

"…in fact, it is difficult to predict the weather and seasons are extreme; if it is dry, it is too dry while the wet season comes with excessive destructive flood. For a few years now, it is impossible to predict the weather correctly and plan well when to plant crops like it used to happen before." [IDI _AS112, male; age 21]

Participants also noted that unexpected heavy rains followed by prolonged dry periods intensify water insecurity by simultaneously destroying livelihoods and reducing future water availability.

"…our water challenges are twofold. During the wet season, we experience flooding due to excessive water. In the dry season, there's no water at all. We're dealing with extremes—either too much water or too little. For example, we rely on nearby wells in the dry season, but they're insufficient." [FGD_CS, male; age45-64]

"It can be confusing. Sometimes the rain comes too early, too much and for too long, causing a lot of damage and havoc. Sometimes it is very hot and dry for too long and the sun is intense when you were expecting rains. That makes it difficult to plan and do your things well." [IDI _AC046, female; age 54]

c) Topography contributes to occurrence of water insecurity

Participants described the physical landscape of their communities as flat and low-lying, a condition that intensifies water insecurity across seasons. During the rainy season, these topographical features were reported to promote flooding, while in the dry season they contributed to falling water tables and the drying up of wells, leaving households without accessible water unless they could afford expensive drilling or alternative sources.

"I can say it is the way the land is. We are on the Kano Plains, which is flat and has clay soil. So what happens is that a lot of water comes from the highlands and it is too much for the river and spills into our settlements. Our settlements now become flooded because of the flat terrain and the bad soils that don't allow water to go into the ground quickly. I believe that is why we have that flooding problem all the time." [IDI_AC039, female; age 33]

"This area is flat, so during heavy rains, there is flooding and it causes a lot of damage, even getting into houses, and sometimes, people are displaced and forced to leave their homes and seek refuge in places like schools or other higher grounds." [IDI_AS058, female; age 39]

They also described poor drainage as conditions that directly expose households to ground water scarcity, reducing access to water sources.

"The cause of the water problems, in this village, the soils are a problem, even if you drill/ dig a well, you must go really deep to get potable water, otherwise, where well-diggers reach, we only get salty and hard water" [IDI_AS044, female; age 52]

These participant accounts show how environmental and climatic conditions in the study area shape water availability and access, creating persistent vulnerabilities to water insecurity among adults on ART. Additionally, the environmental vulnerabilities triangulate with findings from the baseline analysis, where environmental and geographical factors like drought/lack of rainfall and flooding were identified as socio-ecological drivers of water insecurity among adults on ART in the study area.

2) Frequent displacement by floods affects life, livelihoods and HIV management

Displacement from settlements due to flooding emerged as an important lived experience by PLWH. Participants gave accounts of how flooding disrupted their daily lives, livelihood activities, nutrition, health, and HIV management. From their accounts, floods damaged their houses, destroyed household property, swept away crops and livestock, leading to substantial livelihood losses. According to narrations by those who had been affected, displacement to temporary shelters or rescue centers came with additional hardships like overcrowding, limited food, inadequate privacy, and poor sanitation.

> *"For me, staying close to the river causes flooding, which damages my house and property and kills my chickens. I have been displaced because of flooding that even caused the house to collapse, and I had to seek accommodation elsewhere because it was no longer safe to remain in my home. The flood water washes away everything in its path, we lose our food crops and other property and become even poorer." [FGD_CS, female; ages 35-44]*

> *"During the rainy season, there is flooding and damage to houses, displacing some people; the water gets into houses, causing dampness, damaging property, and leading to waterborne diseases such as malaria and pneumonia and illnesses such as the flu." [FGD_CS, female; ages 35-44]*

> *"Flooding makes life miserable; we can't even stay in our houses because they get flooded. This leads to displacement, and we must seek shelter on higher ground or in places like schools until the water subsides." [FGD_BS, male; ages 45-64]*

> *"Sometimes the floods displace us from our homes, so we seek refuge in a certain center that was built by Japanese to serve as a rescue center. At the rescue center, there are usually too many people. It is crowded, there is no orderliness, sometimes you are there with your children, you have no income, there is no food to eat, it is just survival. You see a few people around you cooking and eating, but you can only watch them eat. We experience a lot of despair there…There are two toilets but they are now spoilt and in bad shape. It is really terrible. I fell very sick. People live in appalling conditions at the camp." [IDI _AC046, female; age 54]*

Whenever there were heavy rains and flooding, many participants were forced to flee quickly as rising water sometimes submerged homes and entire villages, preventing them from taking with them essential items, including their HIV medication.

> *"Sometimes when there is flooding, I have to quickly evacuate, and that usually interferes with the time that I should take the medicines so sometimes I take it late because of being displaced from home to higher drier grounds." [IDI _AS112, male; age 21]*

> *"When the whole village is covered in water and you see only the roofs above the water, sometimes you can't tell which house belongs to whom, then I end up skipping the medicine if I left in a hurry and forgot to carry it." [IDI _AC046, female; age 54]*

3) Limited access to adequate, usable water constrains daily life activities of adults on ART

Structural drivers of water insecurity, including environmental, policy and governance, infrastructural, and socio-economic factors, constituted limitations of access to adequate, safe water. Limitations in water access in turn determined the daily living and survival conditions of adults on ART, influencing how routine household and personal activities were organized and managed.

a) Unreliable and risky water sources limited usable supply

The most prominent water insecurity issue for most participants was limited access to reliable, adequate, and safe water sources. Participants described unreliable water points and poor-quality alternatives like streams shared with livestock, which at times led to failed collection attempts and repeated trips or postponed trips.

> *"Getting water is a challenge because sometimes you can fail to get water from the water well, and when going to the stream, the water is very dirty and unusable as cattle also drink from the stream. So, at times, I just come back and try again the next day to buy from the well." [FGD_BS female; ages 45-64]*

While many lived near several surface water sources like the Lake Victoria and large rivers, that proximity did not guarantee access, as accessing the sources was described as difficult, strenuous, and at times dangerous. For example, participants explained that dykes built along riverbanks to prevent flooding unintentionally created new physical barriers to reaching water sources.

> *"Because of the perennial flooding, a dyke was built on the riverbanks to prevent the water from spilling into settlements. Now for me, that is a problem that makes it hard for me to access the water, because I must climb up the dyke before descending to the river, and I must again climb up from the canal and climb up the dyke after drawing the water. It is difficult and I can't make enough trips." [IDI_AC046, female; age 54]*

Even where improved sources existed, participants noted that private control of infrastructure restricted access and imposed additional costs, making water unaffordable for some households.

> *"Because of shortages, the owners of the wells/ boreholes can restrict the amount of water each person gets to one or two containers, meaning I don't get nearly enough for household use." [FGD_BS female; ages 35-44]*

> *"I have once slept hungry as I came back late and tried to go fetch water which is a borehole in someone's home, the owner had closed their gates and so sent me away… I had to make do with no water and went to bed without cooking." [FGD_BS female; ages 35-44]*

Participants described challenges with household water storage. Those who could harvest rainwater, or who could fetch water from available sources, complained that limited storage capacity prevented them from storing it, so that there was rarely enough for use at home.

> *"Lack of adequate water storage facilities is also a problem; myself I have only three jerrycans, so even when it is raining, I don't bother to harvest any from the roof knowing very well I have nowhere to store the water for future use." [FGD_CS female; ages 35-44]*

> *"The biggest barriers are the distance to the borehole, the time it takes to fetch water, and the lack of storage facilities. The borehole sometimes breaks down because so many people use it, and repairs take a long time. That makes it even harder to get water." [IDI _CS033, male; age 17]*

These narratives on inadequate capacity to store water are supported by the quantitative findings which showed that only 13.4% of 434 participants had adequate water storage facilities to ensure household water access

b) Time displacement and erosion of daily routines

Time displacement, a situation where time spent on one activity takes away time that could have been used for other activities, often more important or beneficial; emerged as a structural constraint that undermines adherence, self-care, and livelihoods. Participants repeatedly narrated competing time demands, with the time lost to water collection often conflicting with other day to day activities like schooling, income generation, food preparation, medication schedules and clinic visits. They described an average turn-around time of one to two hours per trip to fetch just one 20L jerrycan of water. From the experiences of participants, it took too much time to obtain enough water required per day for domestic use. The constant negotiation between securing water and

attending to other requirements left them feeling trapped between survival needs and care responsibilities.

> *"It affects my education a lot. When I come home from school, my mother often asks me to fetch water before I can study. Most of my free time is spent getting water, which leaves me little time for homework. It makes me feel bad because I want to focus on my studies." [IDI_CS033 male; age 17]*

> *"On the days I go for water, I cannot do anything else; no livelihood activities whatsoever – just one trip takes too long to make. It is the day when you cannot earn any income because there will be no time for that." [FGD_CS female; ages 35-44]*

> *"Water problems prevent us from carrying out many activities. Looking for water takes up time we need to earn a living, interferes with our income-generating activities and reduces our earnings. That now prevents us from meeting other basic needs. Sometimes household chores cannot be done, you don't have water to bathe, and many times, we end up giving our livestock water that has been used for washing clothes to drink, because there is just not enough water." [IDI_CS030 male; age 38]*

c) Long distances to safe water sources

Participants described long distances to safe water sources as a major constraint that physically limits how much water they can collect and how they organize their day. The distance reduced the number of trips possible and often forced individuals to devote an entire day to water collection, since accessing usable water required long treks to the sources, often through rough terrain.

> *"The distance to the water source is far, and you can only make a few trips, affecting other spheres of life as it is a laborious and tiring undertaking." [FGD_CS female; ages 35-44]*

> *"I have suffered the water (insecurity) problems for a long time; especially before the well was sunk, we only got water from the river (Nyando), which is very far. A small diversion was made on the river to enable easy and safer access to water, but the water is always brown (unclean). When the water levels are low, its very muddy, so you try to dig it up to help remove the solids and reduce turbidity before fetching it." [IDI_AS058, female; age 40]*

Older adults on ART were rarely able to achieve their daily water needs because of physical exertion. Inaccessible boreholes, limited road networks, and topographical challenges extended collection times, aligning with participants' descriptions of chronic exhaustion.

> *"When fetching water by myself, I carry just 10 liters; and I can make 2 trips, so I bring 20 liters; after 2 trips, I'm so tired because the source is far, and I can't manage a third trip to go get the water." [IDI_AS044, female; age 52]*

"Sometimes I set out to go look for water, but because of my advanced age, fetching water from the river is too strenuous for me, I cannot manage to do it" [IDI_CS034, male; age 60]

"I can only go for so many trips carrying water, a menial, back breaking work that leaves me tired and I cannot go for as many trips as I would need to get adequate water for household use." [IDI_AS057, female; age 50]

These qualitative accounts triangulate with the quantitative study findings from the cross sectional analysis, where long distance to water sources significantly predicted water insecurity (OR = 3.44, 95% CI: 2.17–5.47, $p < 0.001$).

d) Economic barriers restrict access to sufficient water

Participants described how economic constraints narrowed their ability to access safe, adequate water. During dry seasons when water was scarce, water vendors charged exorbitantly for water. Some borehole and well owners also sold water at prices unaffordable for many participants. Consequently, participants were forced to manage with only a few jerrycans of water, far less than they required to take care of their daily domestic and personal use requirements. High prices charged for water by vendors restricted households to purchasing very small quantities that were insufficient to meet basic daily needs.

"First, there is an acute scarcity of water, and even vendors who get it from the lake sell it to us exorbitantly such that we cannot afford to buy from them. Yet it's just the usual, untreated lake water, and many can't afford to get enough. The cost is sometimes as high as KES 50 per 20-liter jerrycan! And this is not enough for the family/ household. That one jerrycan that I can afford is not enough for me to use for cooking, bathing, washing, and drinking, including taking care of the children." [FGD_CS, female; ages 35-44]

4) Water-related loss of livelihoods and food crops deepen economic strain

Almost all participants described declining agricultural yields, interrupted businesses, and livelihood losses because of water insecurity. Prolonged dry seasons interfered with agricultural yields, while seasonal floods were reported to destroy and wash away crops and livestock. For other traders, these conditions made it difficult to access markets, or when they could, they could not get customers. The net effect was reduced household incomes, and participants often had to co-opt other competing needs like healthcare and education in favor of survival needs like purchasing food and water.

"During the rains, you can expect a good harvest, and there are always vegetables. However, it is unpredictable because at times, too much rain washes away the crop, so earnings drop. Thinking about impending rains brings me so much anxiety because I am sure it will destroy my vegetables. In the dry season, the earnings are significantly affected by drought—income is very low because you cannot produce anything meaningful to sell without water." [IDI_CC056, female; age 49]

"Water insecurity adversely affects my economic activities; I am a small-scale farmer growing various crops and vegetables that I harvest and sell, so when there is drought my crops wilt, and during the rainy season with heavy rains, my crops are swept away, and so I cannot earn or I earn very little. So, both little water and excessive water affect my livelihood adversely." [FGD_CS, female; ages 35-44]

"Water insecurity adversely affects economic activities; I am a fishmonger and have to get to the lake shores very early – in some cases, I have to forgo or be late to go to get fish and instead go fetch water if there is no water at all. One trip up and down the hill is not enough, I must do at least two trips to have a reasonable amount of water - this affects my potential earnings for the day." [FGD_CS, female; ages 35-44]

5) Gendered norms and violence during water collection intensify water burdens

Beyond structural barriers to water access, participants also described how social norms shaped who bore the responsibility of securing water for the household. Deep-rooted socio-cultural norms and gender roles emerged as an important dimension of lived experience of water insecurity. Participants described, almost universally, water collection as being the responsibility of women, irrespective of age, health status, or competing care needs.

a) Gendered role expectations place disproportionate water collection burdens on women

Water collection was described as a socially expected and non-negotiable responsibility for women, even when it conflicted with their own healthcare needs or other life circumstances.

"…it is my responsibility to fetch the water, and when the man of the house gets back, and I have not fetched water, it causes conflict- yet on my side, I have a small baby, and I sometimes cannot leave the baby alone to go fetch water, or I must go with the baby to fetch water." [IDI_CC050; female, age 20]

"Women suffer the most because they have to get up in the wee hours to fetch water, the man remains behind, still asleep, and then carry it back home. The water must be adequate for cooking, drinking, bathing, washing, and cleaning. It is the woman's duty to ensure there is enough water for all these things, and it is not easy on us." [FGD_CS, female; ages 45-64]

Women reported being held accountable for household water availability, with expectations reinforced by spouses and family members, regardless of water scarcity.

> *"The woman bears the greatest brunt of water insecurity because the children and the man of the house depend on you for water. When my husband wants water and I tell him there's none, he admonishes me and reminds me that he married me to take care of such things - women have to fetch water and ensure there is water." [FGD_CS, female; ages 45-64]*

Participants described water collection as the foundational task that structures all other household activities, placing women at the center of daily functioning and mobility within the home.

> *"Women suffer the most due to water insecurity. The first thing a woman deals with every morning when she wakes up is water – everything else follows water. The woman needs water to perform any household chores, and so has to get the water, whatever the case, no matter the distance involved; otherwise, everyone in the house will be stuck because they all depend on her. What she goes through to get that water is never a consideration. Before anything can move on in the home – livestock, members of the household, the woman must fetch water for household use. [FGD_AS, female; ages 25-44]*

Men's voices reinforced these experiences recounted by women, confirming that they believed water fetching was primarily the responsibility of women, and when there was no water at home, they had reason to question why, often causing conflicts. They also acknowledged the failure on their own part in ensuring adequate storage at home.

> *"...she has to get up early to fetch water from the river. She is also the one at home most times and has to ensure people eat, bathe, the house is clean, and clothes are cleaned - all these need water and she has to fetch this water... If I don't get water for bathing, she is answerable. I get angry but I try to understand the difficulties because I also know I have not provided enough jerrycans to store water at home." [FGD_CS, male; ages 45-64]*

> *"When I return home very thirsty and find there is no water to drink, sometimes my clothes were not washed, I get annoyed and scold my wife. I must reprimand her." [IDI_CS0534; male, age 60]*

> *"Women bear the greatest brunt of water insecurity because they are responsible for ensuring adequate water for household needs and chores, including ensuring that I have enough water to bathe." [FGD_BS, male; ages 45-64]*

b) Water collection responsibilities expose women to gender-based and intimate partner violence

Participants recounted in detail exposure to violence, harassment and sexual assault, including rape, on the routes to and at collection points.

> *"Women and girls are not safe when going to fetch water. Sometimes you are harassed or attacked on the way or at the water source…"I have to wake up very early before dawn, sometimes at 3.00 am, and I have to find other women who want to go fetch water so that we can go as a group for security reasons. If a woman goes alone, she can be attacked, raped, and even killed." [FGD_CS, female; ages 35-44]*

> *"Another time, my child went to fetch water in River Awach early in the morning while I was away. She and other girls encountered some thugs who accosted them and tried to rape them, but they fought the men while shouting for help. Some nearby villagers heard the screams and ran to their rescue, but they still suffered some injuries from the struggle to escape." [FGD_BS, male; ages 45-64]*

Participants also revealed that the strain of water collection often resulted in domestic tension and intimate partner violence (IPV). At the household level, women reported being beaten or verbally abused by their spouses for not ensuring availability of adequate amounts of water, especially when expectations around household cleanliness and food preparation were unmet. Additionally, they described delays in water collection due to distance and queuing as common triggers for IPV, even when the women had explained the reasons for their late return.

> *"Delays when fetching water also cause conflict. Sometimes you left your husband waiting at home, you take too long to return and when you get home, he is annoyed. He will not spare you, he will give you a beating for delaying him despite telling him there was a long queue at the well. He won't listen, he must beat you. Your partner physically assaults you, causing injury because you are late fetching water… My partner has even sent me away, believing that I was lazy or just refused to fetch water for his livestock, not understanding the challenges I have to go through to fetch the water, and I get angry, and this has caused me experience domestic violence, forcing me to run away to my parents' home! [FGD_CS, female; ages 45-64]"*

> *"This water issue is a problem for many of us. A man will beat you mercilessly because there is no water, yet even you yourself you have no water to bathe or take medicine. I have had to run away many times yet I come from far. I only remember I left medicine in my house after I have reached our home where I was born. That has made me miss taking medicine many times. Finally I just left the way I saw other women leaving." [IDI_AC039, female; age 33]*

> *"I suffer physical violence because there is no water. My husband takes me as a mere woman who should ensure there's water. He expects me to provide drinking water for his livestock, and if I don't do it because there is no water, he slaps me. Violence and conflict also arise because I have to travel far to fetch water, and he does not understand why I take so long before I return, yet the distance is far and I have to wait in queue to fetch*

water. When I get back home, he gives me a beating for being late. That is how water problems cause conflicts between us women and our spouses." [FGD_CS, female; ages 35-44]

6) Chronic water stress affects psychosocial well-being and medication adherence by adults on ART

Chronic stress due to water insecurity emerged as an important source of psychosocial stress among water insecure adults on ART. Participants described persistent worry, anxiety, and mental exhaustion associated with the uncertainty of accessing water needed for daily survival and medication.

a) Stress from water insecurity interferes with ART adherence

Participants described how constant concern about water sometimes distracted them from adhering to medication schedules. While many women reported doing everything possible to ensure they took their drugs as required, some men said they forgot to take their ART medicine or postponed taking it because they were stressed and so focused on water-related problems. Others talked about social disengagement and sleeplessness.

"I worry about water every day. It's all I think about. Sometimes I forget to take my drugs." [IDI_CS033, male; age 17]

"I get stressed as the head of the family, and a lot depends on me; while thinking of these challenges of water – which is far off, and food, I sometimes forget to take medication on time. The first problem I have to deal with is water, followed by food." [IDI _BS003, male; age 47]

"Regarding taking the medication, that is when I get very stressed if there is no water. Even if the medicine is put inside porridge, there must first be water to prepare that porridge. Because of that, I sometimes fail to take the drugs at the right time which is bad for my health." [FGD_BS, male; ages 45-64]

b) Water insecurity is a source of mental ill-health among PWH

Participants described the negative ways in which water insecurity affected their mental well-being and their day-to day lives. Women with HIV especially recounted living in a near-constant state of worry, preoccupation, and mental exhaustion driven by the uncertainty surrounding water access. Participants reported the persistent fear of having "not even a single drop of water", in addition to the essential role of water in day-to-day survival needs and medication adherence. They

described experiencing cycles of despair, anxiety, and anticipatory stress over immediate shortages and unpredictability of future water problems. The chronic stress and uncertainty disrupted sleep, increased stress responses, and interfered with the ability to concentrate on other responsibilities.

> *"Water problems bring a lot of worry. I have suffered hopelessness and stress due to water insecurity because sometimes, there is not even a single drop of water and with scarcity, I keep worrying where I can get water- this is stressful; yet water is essential for life, including taking medication." [FGD_CS, female; ages 35-44]*

> *"Indeed, I experience emotional and psychological difficulties, including feelings of despair, stress, and anxiety due to the lack of water. Even now, I'm already anxious about how much rain will fall and whether it will cause damage like it did previously. I never know what will happen, if things will still be ok by morning. I have had feelings of hopelessness, concern, despair, and stress, especially when I don't have enough money to collect water. Sometimes, I return late and still find myself anxious about going to fetch water because it is a necessity for survival." [IDI _CC056, female; age 49]*

> *"Water insecurity has given me worry and anxiety, because I can't even sleep well at times because I'm worried about getting water the next day and about having to wake up early to go fight for water at the river. It can even give you high blood pressure worrying about where to get water during acute shortages. It is hard to sleep or focus on other things, even when attending to other things, all my thoughts are on water." [FGD_CS, female; ages 35-44]*

> *"During floods, I cannot fall asleep at night. Any small sound and you are up. There is water everywhere, mud, snakes…living becomes very difficult. I am never at peace during the rainy season. Just the thought of rain gives me a lot of stress and anxiety because I know trouble is coming for sure. I cannot relax, I am always thinking about what will happen. My mind cannot rest especially during the night. My heart feels like it is sinking all the time. A few days ago it rained. I kept asking myself how I am going to survive, where will I take my daughter and her baby, it is a very stressful time for us." [IDI _AC046, female; age 54]*

> *"I developed chest problems and could not fetch water; my children had also left and I had no one to send for water which made the situation worse. Sometimes I lacked the money to send someone to fetch me water. I felt hopeless and helpless. I was always worried, how will I cook, how will I get water to drink, how will I take my medicine? All this worrying all the time. I could not sleep. I even stopped talking to people until the rains came again." [FGD_CS, female; ages 45-64]*

7) Water insecurity contributes to consumption of unsafe water, increasing risk of physical illness

Reliance on unsafe and untreated water exposes adults on ART to recurrent illness as they prioritize immediate survival and medication needs over water safety.

a) Consumption of unsafe water

Participants described being compelled to consume unsafe water to meet their medication and other immediate needs. It included drinking untreated water as collected from the source and relying on push-cart vendor-supplied water of uncertain quality, both of which were perceived to increase episodes of water-related illness.

> *"For me to remain healthy, I must take my medication on time, and when there is no water in the house, I will do anything to get some, even if it means going to drink untreated water at the well so that I don't miss taking the medicines as scheduled." [IDI _BS005, male; age 47]*

> *"We mostly get water from ponds or shallow water pans. When it rains, they collect water, which we use in the dry season for livestock. Many people also rely on the water from the open pond for cooking, though it's unsafe and needs treatment." [FGD_CS, male; ages 45-64]*

For some participants, lack of financial resources and the discontinuation of hospital-supported water treatment programs resulted in routine use of untreated water at the household level.

> *"We just use the water as fetched; we don't treat it because there is no money to buy water treatment chemicals. Sometimes, though, we used to get water treatment tablets from the hospital, and at that time, we treated the water. But that program stopped, and so we also stopped treating our water." [IDI_CS056, female; age 49]*

> *"Personally, I don't treat it because I can't afford to buy the water treatment tablets- so I fetch and use the water as it is." [FGD_CS, female; ages 35-44]*

Environmental contamination of the lake water as determined by the presence of algal blooms and water hyacinth, was reported to make water unsafe for consumption and was associated with increased water-related illnesses.

> *"We fetch water from the lake, and sometimes, the water is unsafe for human use as it is full of algae; other times, the water hyacinth shows up, covering up the lake and making it inaccessible and is very unsafe for human use. The water is often smelly, you cannot drink it. That is the time we also get many water-related diseases." [FGD_CS, female; ages 35-44]*

Additionally, participants reported that water contamination of sources happened during both the dry and rainy seasons, for example, flooding during the rainy season introduced pollution from surface runoff and wastewater from flooded latrines into water sources, exposing households to contaminated water.

"During the long dry season, lake water turns green and becomes unusable and very dirty. If you wade in to find cleaner water, the green things (algae) stick to your feet. We suffer severe water shortages. When the rainy season comes, the water is excessive and the surface run-off from the uplands comes with a lot of garbage, debris, and even waste water from flooded latrines; contaminating our water sources, meaning we consume dirty water." [FGD_CS, female; ages 35-44]

Some of the participants noted that deceptive practices by pushcart water vendors further exposed households to unsafe water by misrepresenting contaminated sources as safe tap water.

"Most of the water sources we use are not safe. The water is often contaminated. The problem is worsened by untruthful water vendors who may claim they've sourced water from a tap, but in reality, it's from a common pond. If you're not careful, you end up using contaminated water." [FGD_BS, male; ages 45-64]

b) Recurrent water-related illnesses

Participants recounted frequently experiencing and seeking treatment for diarrhea, typhoid, bilharzia, malaria, and skin infections, sometimes affecting entire households. They attributed these illnesses to the use of untreated and presence of stagnant water.

"I sometimes also fetch the stagnant water in pools and puddles for use in the house, which has caused me typhoid because I filter it using a cloth but I do not treat the water with water treatment products. That has made me very sick." [FGD_CS, female; ages 35-44]

"…intestinal worms is a problem due to contaminated water, and there are times we get deworming tablets from the Community Health Promoters who go around the village from house to house. Typhoid is also a problem we have experienced, especially during the heavy rains – I went to the hospital with very high fever and was tested and treated for typhoid. We have also experienced bilharzia – Last November (2024) around the time you first came to talk to me, one of my younger children was suffering from bilharzia and had to be treated for it." [IDI_BS009, male; age 42]

Further, recurrent illness drained finances and heightened anxiety. Participants reported spending scarce income on clinic visits, antibiotics, and vendor water during outbreaks.

"Every month someone is sick because of water, and that means no money for food." [FGD_CS, female; ages 35-44]

Participants described multiple illnesses affecting both adults and children across seasons, including malaria during flooding and gastrointestinal infections during dry periods when unsafe water was consumed.

"Water brings diseases. The children get malaria. Sometimes I get pneumonia because of the extreme cold and dampness. In the dry season, there is water shortage; the water is dirty/unsafe, causing children amoeba and typhoid as the water consumed is unsafe. We then use a lot of money to treat the children" [FGD_CS, female; ages 45-64]

Unsanitary practices at water collection points exposed participants to fecal contamination and, in some cases, prevented them from fetching water altogether. From the water quality tests conducted on communal sources used by these participants, laboratory results confirmed their reports. Several samples contained fecal coliforms and E.coli that exceeded safety standards.

"Reaching the water point, I found someone defecating at the water source- I was so appalled that I decided to come back without fetching water!" [FGD_CS, female; ages 35-44]

The findings above on exposure to contaminated water converge with quantitative findings that showed perceived contamination of sources. Additionally, water contamination was a community-level predictor of water insecurity in this population as was found in mixed effects regression analyses, where chemical contamination (AOR = 2.70, 95% CI: 1.54–4.72, p = 0.001), and microbial contamination (AOR = 3.96, 95% CI: 2.07–7.59, p < 0.001) were independent predictors of water insecurity.

8) Water insecurity disrupts HIV treatment engagement and continuity

Participants described multiple ways in which water insecurity interfered with their ability to consistently engage in HIV care and adhere to treatment. These disruptions include delayed or missed medication doses, missed clinic appointments, and challenges associated with the co-occurrence of water and food insecurity.

a) Delayed and skipped doses

Participants gave emotional accounts of instances when they were compelled to delay their medication or skip taking them altogether when water for taking the medication at the scheduled times was unavailable. In some cases, they would take the medicine inside porridge or just swallow the pills with nothing.

"That happened when there was no water totally; and I would not take the medicines on time or I don't take them at all, adversely affecting my health... I have never forgotten, but I have missed taking medication because there was totally no water to take the drugs with." [IDI _CC050, female; age 20]

"I have been adversely affected by water insecurity because I sometimes don't have water or money to buy bottled water to take the medication with, or get some cold leftover food to eat before I can take the medicine. So, I take medicine late, and it affects my health adversely." [IDI _BS003, male; age 47]

"Sometimes, water has given me challenges with ART adherence. You see, for our well-being, the ARVs have to be taken consistently at specific times or hours depending on the decision you made individually on when to take them. That is the way to ensure you do well on treatment. Sometimes, there is no water in the house, and the time I should take the drugs is elapsing. For me, that is a big problem because of the drugs I am currently taking." [IDI _BS005, male; age 47]

"Water scarcity affects me adversely, especially in the dry season to the extent that I even lack water to take my medication. This has greatly affected my health – the failure to take medicine when I lack water. It has caused me terrible experiences; since we only get water from the stream that often runs dry." [FGD_CS, male; ages 45-64]

Extreme weather, especially floods, was another cause of delayed and skipped doses. According to participants, flooding and ensuing displacement frequently destroyed medication, or caused it to be left behind. For some, the flooding led them to lose their clinic cards which affected their regimens.

"I lost my card and drugs during floods. I had to start all over again after a month." [IDI _AS112, male; age 21]

For some participants, delayed and skipped doses caused them to experience some noticeable side-effects:

"For me, that is a big problem because of the drugs I am currently taking; because if I delay even for a short time, I get side effects – I start getting some eruptions on my skin. That causes me a hard time, such that when there is no water in the house to take the medicine, I cannot function – my head cannot function properly." [IDI _BS005, male; age 47]

b) Missed clinic visits

The dual problem of water scarcity and excessive availability due to flooding was reported by participants as an important cause of missed clinic visits. Participants often skipped clinic or made the visits long after their scheduled appointments because of looking for water, being unable to access the facilities due to damaged roads, or being cut-off by flood waters. For some participants, missed clinic visits led to unfavourable consequences like punishment by the health service providers (HSPs). They were given medication for only a week instead of 3 or more months, to

compel them to visit the clinic more often as a way of enforcing adherence, a strategy that was sometimes counterproductive.

> *"I have missed appointments to go get medication because of having to go look for water. When I get to the clinic late, I am labelled a defaulter, and I'm given drugs for one week only. But I live far from the hospital. At the end of that week, I don't have fare to go back to the clinic for more drugs, and now that will cause me to skip a few doses." [FGD_CS, female; ages 35-44]*

> *"I arrived at the facility and found it closed because I was late; I was unable to arrange the necessary transport on time. Even right now, I don't know what I'm going to do. I was given drugs to last me one week, and I'm due for another appointment but I don't think I can make it on time...I used to go to clinic every six months, but lately, I am given drugs for a month, at times for ten days, sometimes for a week – and it is inconveniencing me because of the many trips to the clinic." [IDI _BS003, male; age 47]*

> *"There are times during the dry season that I lack water for taking the medicine. Other times, I'm due for clinic to get my refill, but then it rains heavily on that day and so I miss clinic. The clinician knows I must go for the medicine, but when I go outside my appointment date, she first refuses to give it to me and instead gives me a serious admonition for defaulting... I end up being given drugs for one week only because of very heavy rains and miss to take medication as required." [FGD_CS, female; ages 35-44]*

c) Co-occurrence of water and food insecurity are barriers to treatment adherence

Participants described how the co-occurring shortages of water and food complicated their ability to adhere to antiretroviral therapy. Some explained that medication taken without food caused unpleasant side effects, while the daily struggle to secure water and food often took priority over maintaining medication schedules.

> *"The ARVs are vicious to the body when you are not eating properly. Food is vital while taking these drugs, so I ensure I get proper, nutrient-rich food; otherwise, I will suffer seriously. Taking the drugs without food is so bad that you can decide to skip the medicine altogether to avoid the nasty experiences from the drugs. I think they are very, very strong." [IDI _BS003, male; age 47]*

> *"I get stressed as the head of the family, and a lot depends on me; while thinking of these challenges of water – which is far off, and food, I sometimes forget to take medication on time. The first problem I have to deal with is water, followed by food." [IDI _BS003, male; age 47]*

Participants described a reinforcing cycle linking water insecurity, food shortages, and HIV treatment challenges: limited water availability contributed to hunger and difficulty taking

medication, while the resulting weakness due to a poor diet reduced their physical capacity to fetch water, further deepening water insecurity.

> *"...if there is drought or flooding from heavy rains, we lose our crops and there is hunger. So, for people like me on prescribed ARVs medication, I suffer from hunger, which affects my ability to comfortably take medication, a weak person can default. For instance, I like taking medication with porridge, so when there is no water or food, I suffer a lot because taking medication without food causes me side effects... I get nausea or heartburn, and it affects my ability to go get occupied. Recently, I even lost my appetite and also lost some weight…when I have inadequate food, sometimes I only took porridge last night, and I have taken medication, I don't have the energy to do hard work like walking a long distance to go fetch water or make another trip." [IDI _AS058, female; age 40]*

d) Potential viral rebound due to non-adherence

Some water insecure participants described experiencing increased viral load, which health service providers attributed to frequent missed or delayed doses.

> *"...sometimes, my viral load increases due to failure to take medicine on time. Failure to get water in time to take medicine is endangering my life right now...Three months ago when I was feeling unwell and went to hospital, they tested me and said I had TB and must be isolated…After that, they spoke about the frequent changes in my time for taking medications as the cause of my illness and increased viral load.." [IDI _BS003, male; age 47]*

From this last theme on treatment interruptions, many more males, than females interviewed reported disruptions in ART due to water insecurity and disengagement from care, unlike the first seven themes where there were more female than male voices.

Overall, these qualitative accounts on water-related HIV treatment interruptions converge with evidence from the case–control analysis that showed significantly higher odds of unsuccessful HIV treatment outcomes among water-insecure participants in unadjusted (OR: 3.18; 95% CI: 1.96–5.17; $p < 0.001$) and in adjusted (AOR: 3.66, 95% CI: 2.13–6.29, $p < 0.001$) analyses.

In summary, the eight themes above collectively illustrate how water insecurity is experienced by adults on ART as a multi-layered and interconnected challenge shaped by environmental, structural, and social conditions. Participants described how environmental vulnerabilities such as flooding, drought, and unfavorable topography constrained water availability, while structural barriers including distance, unreliable sources, and economic limitations restricted access to adequate and safe water. These conditions compelled households to rely on unsafe water sources,

contributing to recurrent illness and increased financial strain. At the same time, gendered norms placed the primary responsibility for water collection on women, exposing them to heightened physical burdens and risks of violence. Extreme weather events, particularly flooding, further disrupted livelihoods, displaced households, and intensified psychological stress. Across these experiences, participants consistently described how water insecurity interfered with daily routines, food preparation, and medication schedules, ultimately disrupting engagement with HIV treatment and care. Building on the lived experiences described above, the analysis identified a set of pathways through which water insecurity shapes daily life, health, and engagement in HIV care among adults on ART in Kisumu County.

4.4.2 Pathways from water insecurity to HIV treatment outcomes

The following pathways (Table 4.9) were inductively derived from participants' narratives by grouping related themes into mechanism-based categories using framework analysis, and then elucidating how each mechanism links water insecurity to HIV treatment outcomes. They are findings derived from the lived experiences data, and have no bearing on the a priori study conceptual framework derived from literature review and study variables to guide the study design, despite some similarities with intermediate variables in the study conceptual framework.

Participants' accounts showed that water insecurity affects health and HIV care through multiple, interrelated pathways. These include environmental shocks and mobility pathways linked to displacements due to flooding; resource insecurity (food, economic) pathways due to competing household and survival needs; gendered and relational pathways linked to safety risks and unequal responsibilities for water acquisition; physical health pathways related to the use of unsafe water and recurrent water-related illness; psychosocial pathways characterized by stress, anxiety, and emotional distress; and water-dependent dosing pathways, whereby ART intake is contingent on immediate access to water. These pathways did not operate in isolation but frequently overlapped and reinforced one another in participants' daily lives, with various coping and adaptation (including maladaptive) strategies.

Across these pathways, a common pattern emerged: water insecurity constrained participants' ability to maintain normal daily routines, protect their physical and mental health, ensure personal safety, and consistently engage in HIV care. Drawing on the Capability Approach, these constraints are conceptualized as losses in key capabilities that are necessary for sustaining

treatment adherence and continuity of care. Individual, social, and environmental factors shaped how these constraints were experienced, leading to variation in the severity and consequences of water insecurity across participants.

When these capability constraints accumulated, participants described disruptions in HIV treatment, including missed doses, delayed or missed clinic visits, and challenges sustaining uninterrupted care. Importantly, these treatment disruptions were not framed by participants as matters of individual choice or non-compliance, but as outcomes of layered structural, environmental, and social pressures associated with persistent water insecurity.

Table 4.9: Pathways linking water insecurity to HIV treatment outcomes among adults on ART in Kisumu County

	Pathway	Hypothesized mechanisms of action to HIV treatment outcomes
1.	Environmental shocks and mobility	• Extreme weather events like floods disrupt stable living conditions through displacement, relocation, and loss of household assets including medication. • Forced movement and temporary resettlement interfere with continuity of care by limiting privacy, limiting access to clinics, undermining hygiene and sanitation, and disrupting routines. • These disruptions contribute to missed doses, delayed refills, and interruptions in HIV care continuity.
2.	Resource insecurity	• Water insecurity constrains access to essential household and economic resources, including food, income, and assets, while also limiting the livelihood activities that could sustain these resources. Such deprivations limit the capacity to meet certain treatment-related needs. • Water insecurity has a direct influence on the ability to produce or acquire food, and affects food preparation at the household, compromising the nutritional status of participants. Poor nutrition is directly associated with poor HIV treatment outcomes. • Economic strain limits the ability to afford transportation costs to health facilities, purchase food, safe water, and maintain consistent engagement in care. • Households cope by reallocating available time, income, and material resources towards securing water, further exacerbating trade-offs that undermine treatment adherence.
3.	Gendered and relational	• Gendered roles due to cultural norms habitually put women at risk of IPV, which can cause physical, sexual, and emotional harm; sometimes forcing victims to flee, thus disrupting stability and daily routines and in turn leading to treatment interruptions like missed doses and clinic visits. • Water acquisition exposes some participants, particularly women, to safety risks, including sexual harassment and assault.

		• Fear, fatigue, or relationship strain limit autonomy and time available for clinic attendance and treatment routines. These relational constraints indirectly undermine consistent engagement in HIV care.
4.	Psychosocial	• Persistent uncertainty about water access leads to chronic stress, anxiety, and emotional exhaustion, reducing the motivation and cognitive bandwidth needed to prioritize medication-taking and clinic engagement. • Over time, stress-related disengagement contributes to delayed and missed doses, missed clinic visits, and ultimate disruptions in HIV care continuity.
5.	Physical health	• Frequent reliance on unsafe or contaminated water predisposes participants to recurrent water-related illnesses, which weaken physical functioning and complicate day-to-day management of HIV. • Episodes of illness interfere with clinic attendance and consistent ART use, especially during acute symptoms. • Additional financial burden of treating water-related illnesses constrain resources needed for transport and engagement in HIV care, contributing to treatment interruptions. • The use of contaminated/unsafe water and reduced hygiene practices as coping responses increase exposure to illnesses which reinforce this pathway.
6.	Water-dependent dosing	• Inadequate availability of water at the time of medication-taking directly limits participants' ability to take ARVs as prescribed. • Lack of water to swallow pills or prepare food leads to delayed or skipped doses, especially when medication must be taken with water or alongside meals. • These immediate constraints contribute directly to intermittent adherence and treatment interruptions.

Findings from the cross-sectional and qualitative studies were synthesized into a novel conceptual model (Figure 4.7) that integrates socio-ecological drivers and dimensions of water insecurity, lived experiences, and empirically derived pathways, to illustrate how structural and environmental drivers shape multidimensional water insecurity, which operates through several mediating pathways.

The novel conceptual model (appearing at the end of this chapter) illustrates how structural determinants shape multidimensional water insecurity, which influences HIV treatment outcomes through capability-eroding pathways, moderated by conversion factors.

This framework, while drawing from the lived experiences, synthesizes findings across the study objectives to illustrate how water insecurity operates as a socio-ecological and multidimensional condition influencing HIV care. At the upstream level, structural, environmental, and social drivers

shape the availability, access, and quality of water. These dimensions define the lived experience of water insecurity as persistent challenges related to unreliable supply, unaffordable or distant sources, and unsafe water for daily use. Rather than occurring as isolated events, these experiences are embedded in broader environmental and social contexts that limit individual control over water access.

Building directly on participants' lived experiences, the model identifies several interrelated pathways through which water insecurity affects daily life and health. Although presented as distinct, these pathways frequently overlap and reinforce one another, producing cumulative effects rather than operating independently.

Guided by the Capability Approach, the model shows how these interacting pathways converge to constrain key capabilities necessary for sustaining health and HIV care, including the ability to maintain daily routines, safeguard physical and mental health, ensure safety and dignity, secure adequate nutrition, and consistently engage with health services. Individual, social, and environmental conversion factors determine how lived water insecurity translates into capability constraints, resulting in variation in outcomes across individuals and households. When capabilities are constrained, disruptions in health functionings emerge; manifested as delayed or missed doses and clinic visits, and difficulties maintaining uninterrupted HIV treatment. The model thus emphasizes that treatment disruptions arise from cumulative structural and experiential constraints associated with water insecurity, rather than from individual non-compliance alone.

4.5 The association of water insecurity with HIV treatment outcomes among adults on ART

Among 384 randomly selected adults on ART, 356 pair-matched participants (181 cases and 175 controls), were reached of which 61.2% were female, 52.8% were married, the largest proportion of participants had completed primary education (48.0%), and 71.1% overall experienced water insecurity. Participants were matched on age, sex, and time on ART. The median age was 45 years (IQR: 36 - 53.5), and the median duration on ART was 14 years (IQR: 9 - 17). Most participants (65.2%) lived in semi-permanent housing.

Using manual computation, the results below showed that water insecurity was more prevalent among cases (82.3%) than controls (60.6%). From this crude analysis, water-insecure participants had three times the odds of poor HIV treatment outcomes compared with water-secure participants

(OR= 3.03; 95% CI: 1.86–4.94), corresponding to a computed relative risk (RR) of 1.84; 95% CI: 1.36–2.50 meaning; water-insecure participants had almost two times the risk of HIV treatment outcomes compared those who were water-secure:

	OUTCOME				
	HIV Treatment Outcome +VE		HIV Treatment Outcome -VE		
Exposed	**a**	149	**b**	106	**255**
Unexposed	**c**	32	**d**	69	**101**
		181		**175**	**356**

OR = (a × d) / (b × c); OR = (149 × 69) / (106 × 32) = 10281/3392

OR = 3.030955 = 3.03

95% CI = ln (OR) ± 1.96 × SE, but, SE = √ (1/a + 1/b + 1/c + 1/d)

SE = √ (1/149 + 1/106 + 1/32 + 1/69)

1/149 = 0.00671; 1/106 = 0.00943; 1/32 = 0.03125; 1/69 = 0.01449.

0.00671 + 0.00943 + 0.03125 + 0.01449 = 0.06188

SE = √0.06188; SE = 0.249

Ln (OR) = ln (3.03); ln (OR) = 1.109

95%CI = ln (OR) ± 1.96 × SE

1.96 × 0.249 = 0.488 Therefore:

Lower limit = 1.109 − 0.488 = 0.621; exp (0.621) = 1.86

Upper limit = 1.109 + 0.488 = 1.597; exp (1.597) = 4.94

Thus:

OR = 3.03 **RR = 1.84**

95% CI = (1.86 – 4.94) **95% CI = (1.36 – 2.50)**

	CASES	CONTROLS			OR:	3.03	(95% CI: 1.86 – 4.94)
Water Insecure	149	106	255				
Water Secure	32	69	101		**Prevalence of WI**	**71.6%**	
	181	**175**	**356**		Among Cases	**82.3%**	
					Among Controls	**60.6%**	

4.5.1 Overall association between water insecurity and HIV treatment outcomes

In unadjusted analyses, individuals who were water insecure had over three times the odds of poor HIV treatment outcomes (OR: 3.18; 95% CI: 1.96–5.17; $p < 0.001$), compared to individuals who were water secure (Table 4.10).

Longer duration on ART was associated with slightly increased odds of poor HIV treatment outcomes (OR: 1.05; 95% CI: 1.01–1.09; $p = 0.018$). Participants living in temporary housing had almost two times the odds of poor HIV treatment outcomes compared with those in semi-permanent housing (OR: 1.91; 95% CI: 1.16–3.16; $p = 0.011$). Other socio-demographic variables, including age, sex, marital status, education level, and clinic site, were not significantly associated with the outcome in univariate analyses.

After adjusting for matching variables and other covariates, water insecurity remained independently associated with poor HIV treatment outcomes (AOR: 3.66, 95% CI: 2.13–6.29, $p < 0.001$). Similarly, duration on ART remained a predictor of poor HIV treatment outcomes (AOR: 1.05; 95% CI: 1.01–1.10; $p = 0.015$). Temporary housing showed a strengthened association in the adjusted model (AOR: 3.37; 95% CI: 1.71–6.65; $p < 0.001$).

Clinic site was significantly associated with HIV treatment outcomes in the adjusted analysis. Compared with Ahero, participants receiving care at Kombewa had lower odds of poor HIV treatment outcomes (AOR: 0.37; 95% CI: 0.19–0.72; $p = 0.004$), while no significant difference was observed for Nyakach. Age, sex, marital status, and educational attainment were not statistically significant in the adjusted model.

Among the population on ART in Kisumu (116, 534), 96% (111,976) were virally suppressed, giving a suppression gap of 4%.

This means that the case-control study met the rare disease assumption (<10% prevalence of outcome in the reference population). Therefore, the OR approximates the Relative Risk (RR) of HIV outcomes, given exposure to water insecurity.

Table 4.10: Unadjusted and Adjusted association of water insecurity and selected covariates with HIV treatment outcomes among PLWV (N=356)

Predictor	n (%) or median (IQR)	OR (95% CI)	p-value	AOR (95% CI)	p-value
Water insecurity					
Water secure	103 (28.9%)	Ref			
Water insecure	253 (71.1%)	**3.18 (1.95 - 5.17)**	**<0.001**	**3.66 (2.13–6.29)**	**<0.001**
Age: median (IQR)	45 (36.0, 53.5)	1.00 (0.98 – 1.02)	0.944	0.99 (0.97 – 1.02)	0.799
Sex					
Male	138 (38.8%)	Ref			
Female	218 (61.2%)	1.34 (0.87 – 2.05)	0.180	1.05 (0.59–1.88)	0.860
Time on ART (yrs) median (IQR)	14 (9.0, 17.0)	**1.05 (1.01-1.09)**	**0.018**	**1.05 (1.01 - 1.10)**	**0.015**
Marital status					
Currently married	188 (52.8%)	Ref			
Never married	52 (14.6%)	0.82 (0.44 – 1.52)	0.531	0.79 (0.30–2.10)	0.634
Separated	14 (3.9%)	1.73 (0.56 – 5.34)	0.344	0.95 (0.25–3.58)	0.943
Widowed	102 (28.7%)	1.00 (0.62 – 1.61)	0.989	0.69 (0.36–1.30)	0.251
Educational attainment					
None	116 (32.6%)	Ref			
Primary complete	171 (48.0%)	0.67 (0.41–1.07)	0.094	0.65 (0.37–1.15)	0.140
Secondary complete	39 (11.0%)	0.55 (0.26–1.14)	0.105	0.65 (0.27–1.55)	0.331
Vocational	30 (8.4%)	0.54 (0.24–1.21)	0.136	0.88 (0.33–2.40)	0.810
Housing type					
Semi-permanent	232 (65.2%)	Ref			
Temporary	89 (25.0%)	**1.91 (1.16 – 3.16)**	**0.011**	**3.37 (1.71–6.65)**	**<0.001**
Permanent	35 (9.8%)	0.95 (0.47 – 1.94)	0.889	1.02 (0.45–2.33)	0.961
Clinic site					
Ahero	124(34.8%)	Ref			
Nyakach	118(33.2%)	1.19 (0.72-1.97)	0.505	1.26 (0.71–2.25)	0.426
Kombewa	114(32.0%)	0.84 (0.51-1.40)	0.506	**0.37 (0.19–0.72)**	**0.004**

- **OR 3.18 (1.95–5.17):** The lower bound (1.95) is nearly double the null value (1.0). This shows a very stable result.
- **AOR 3.66 (2.13–6.29):** Even after adjustment, the lower confidence bound of 2.13 still shows that water insecurity more than doubles the odds of HIV treatment outcomes.

These findings converge with the qualitative results presented earlier, where participants described delaying or skipping medication doses when water was unavailable, and missed clinic visits due to water-related time displacement and logistical challenges, findings that resonate with the increased odds of poor HIV treatment outcomes associated with exposure to water insecurity in Table 4.10.

4.5.2 The association between water insecurity severity and HIV treatment outcomes

Water insecurity severity was strongly associated with HIV treatment outcomes. In the categorical model, participants experiencing 'low' water insecurity had significantly higher odds of poor HIV treatment outcomes compared with those experiencing 'no–marginal' water insecurity (OR = 7.06; 95% CI: 2.58–19.36; $p < 0.001$) (Table 4.13). Similarly, 'moderate' water insecurity was associated with increased odds of poor treatment outcomes (OR = 6.80; 95% CI: 2.77–16.73; $p < 0.001$). Participants experiencing 'high' water insecurity had markedly elevated odds of poor HIV treatment outcomes compared with the reference group (OR = 61.81; 95% CI: 19.41–196.81; $p < 0.001$). The large magnitude of the estimate for the 'high' water insecurity category reflects the concentration of cases (59) relative to controls (7) within this group.

Since the 'high' water insecurity category contained considerably fewer controls, Firth's penalized logistic regression was conducted as a sensitivity analysis to assess potential sparse-data bias. The penalized estimates were similar to those from the standard logistic model, with 'low' (OR = 6.60; 95% CI: 2.47–17.59; $p < 0.001$), and 'moderate' (OR = 6.35; 95% CI: 2.66–15.19; $p < 0.001$) water insecurity associated with six times the odds of poor HIV treatment outcomes, compared to 'no-low' water insecurity. 'High' water insecurity was associated with substantially elevated odds of poor HIV treatment outcomes, compared to 'no-low' water insecurity (OR = 54.31; 95% CI: 17.72–166.44; $p < 0.001$).

When water insecurity severity was modelled as a continuous variable, results in Table 4.13 show that the likelihood of poor HIV treatment outcomes increased progressively with greater water insecurity severity: Each five-point increase in the water insecurity score was associated with approximately a twofold increase in the odds of poor HIV treatment outcomes (OR = 2.05; 95% CI: 1.72–2.44; $p < 0.001$).

Table 4.11: Associations between water insecurity severity and HIV Treatment Outcomes

Water insecurity exposure	n (%)		OR	p-value	95% CI
Categorical severity	Cases	Controls			
No–marginal (0–2)	06 (12)	44 (88)	1.00	Reference	
Low (2–11)	26 (49.1)	27 (50.9)	7.06	**<0.001**	2.58–19.36
Moderate (12–23)	90 (48.1)	97 (51.9)	6.80	**<0.001**	2.77–16.73
High (24–36)	59 (89.4)	07 (10.6)	61.81	**<0.001**	19.41–196.8
Continuous severity					
5-point increase in WI score	181(50.8)	175 (49.2)	2.05	**<0.001**	1.72 - 2.44

4.5.3 Sex as a modifier of the association between water insecurity and HIV treatment outcomes

Effect modification by sex was assessed by including an interaction term between water insecurity and sex in a multivariable logistic regression model (Table 4.11). Among **males**, water insecure men had four times the odds of poor HIV treatment outcomes (OR = 4.37; 95% CI: 2.04–9.36; p < 0.001) compared to water secure men. Among **water-secure participants**, females had almost two times the odds of poor HIV treatment outcomes compared with males, but this difference was not statistically significant. The interaction term between water insecurity and sex showed that the odds of a poor HIV treatment outcome for water-insecure females was 0.55 times (or 45% lower) than the odds of a poor outcome among water insecure males; but it was not statistically significant (OR = 0.55; 95% CI: 0.20–1.48; p = 0.236), giving no evidence that the association between water insecurity and HIV treatment outcomes differed by sex.

Table 4.12: Adjusted estimates of sex as a modifier of association (N=356)

Parameter	AOR (95% CI)	p-value
Water insecurity (Male)	4.37 (2.04–9.36)	<0.001
Female (Water secure)	1.78 (0.76–4.15)	0.181
Water insecurity × Female	0.55 (0.20–1.48)	0.236

While the cross-sectional and qualitative findings highlighted gendered experiences of water insecurity, the case–control analysis found no evidence that sex modified the association between water insecurity and HIV treatment outcomes. This could appear as a divergence in findings, but they answer different questions: The cross-sectional and qualitative questions ask how gender shapes the experience of water insecurity (water insecurity is the outcome), whereas the case-control question seeks to establish whether the HIV treatment outcomes among participants who have water insecurity differ statistically by sex.

4.5.4 Predicted probabilities of poor HIV treatment outcomes by water insecurity and sex

Predicted probabilities derived from the interaction model further illustrated these findings (Table 4.12). Water insecurity substantially increased the probability of poor HIV treatment outcomes for both sexes. Among males, the probability increased from 25.0% (95% CI: 13.2% – 36.8%) among the water secure to 59.3% (95% CI: 48.9% – 69.7%) among the water insecure males. Similarly, among females, the probability increased from 37.2% (95% CI: 24.0% – 50.5%) among the water secure to 58.7% (95% CI: 51.2% – 66.2%) among the water insecure females. From this data, the lowest predicted probability of poor HIV treatment outcomes occurred among water-secure males (25%), while probabilities among water-insecure males (59.3%) and females (58.7%) were nearly identical.

Table 4.13: Adjusted predicted probabilities of poor HIV treatment outcomes by water insecurity and sex (N=356)

Water insecurity status	Sex	Adjusted predicted probability	95% CI
Water secure	Male	25.0%	13.2% – 36.8%
Water secure	Female	37.2%	24.0% – 50.5%
Water insecure	Male	59.3%	48.9% – 69.7%
Water insecure	Female	58.7%	51.2% – 66.2%

In figure 4.7 below, water insecurity substantially increases the probability of poor HIV treatment outcomes for both sexes. While females exhibit a higher baseline probability than males under water-secure conditions, the probabilities rise and converge under water insecurity, becoming nearly identical for males and females. The overlapping confidence bands under conditions of water insecurity for both sexes further confirm the absence of interaction.

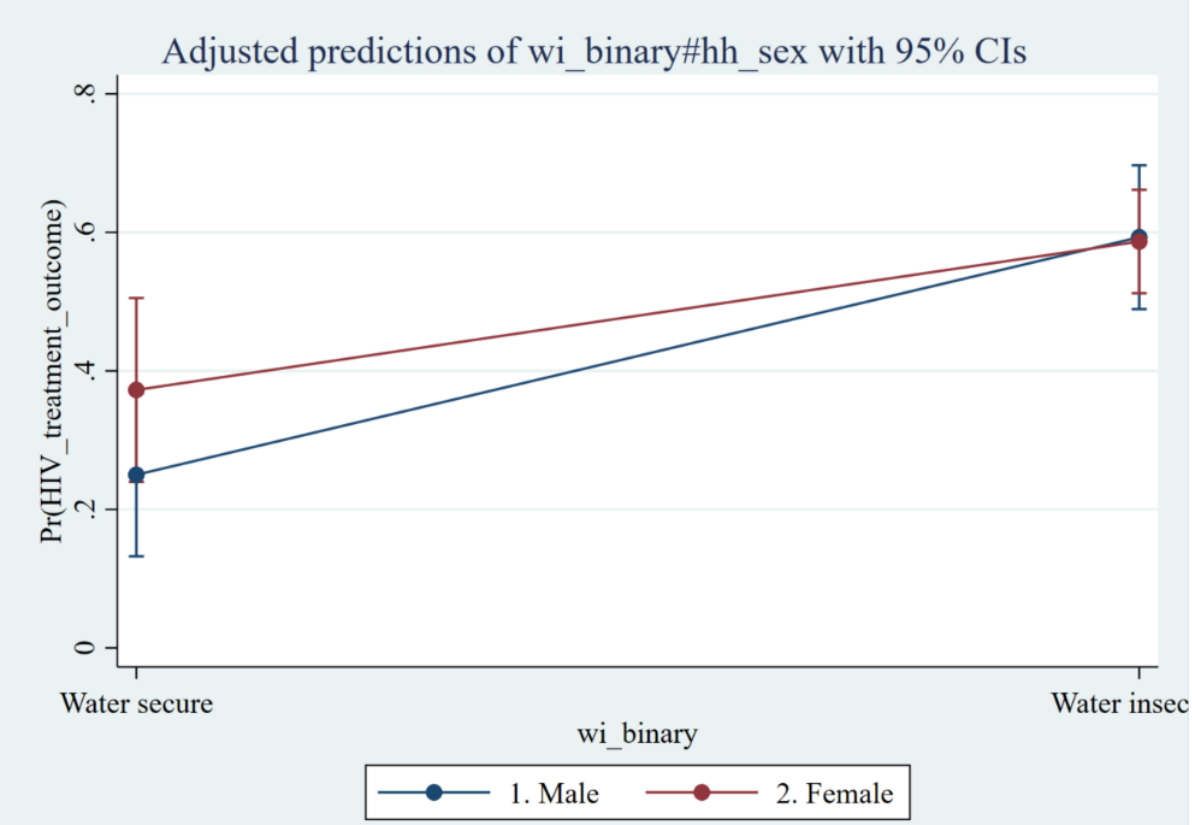


Figure 4.6: Predicted probabilities of HIV treatment outcomes by water insecurity status and sex

4.5.5 Secondary analyses of intermediate variables

Apart from the primary analyses, secondary associations between the independent, intermediate, and dependent variables as hypothesized in the study conceptual framework (Figure 2.1) were examined and the results presented in Table 4.14. Mediation analysis was not the primary objective of this study, so these analyses were only done to illustrate the plausibility of the hypothesized intermediate variables and not to interpret the findings. Water insecurity was significantly associated with higher food insecurity scores ($\beta = 5.44$; 95% CI: 3.99–6.89; $p < 0.001$), higher depression scores ($\beta = 1.89$; 95% CI: 0.96–2.82; $p < 0.001$), higher anxiety scores ($\beta = 2.05$, 95% CI: 1.11–2.99, $p < 0.001$), and greater odds of reporting water-related illness (OR = 5.09; 95% CI: 2.55–10.13; $p < 0.001$). The association between water insecurity and reported challenges in accessing ART did not reach statistical significance though the odds of the outcome were increased

(OR = 1.56; 95% CI: 0.51–4.82; p = 0.440). Put differently, participants experiencing water insecurity had, on average, 5.44 points higher food insecurity scores, 1.89 points higher depression scores, and 2.05 points higher anxiety scores than those who were water secure.

On the other hand, each intermediate variable was significantly associated with HIV treatment outcomes. Higher food insecurity (OR = 1.09; 95% CI: 1.06–1.13; p < 0.001), depression (OR = 1.17; 95% CI: 1.10–1.24; p < 0.001), and anxiety (OR = 1.11; 95% CI: 1.05–1.17; p < 0.001) scores were associated with increased odds of poor HIV treatment outcomes. Water-related illness (OR = 2.36; 95% CI: 1.17–4.74; p = 0.016) and challenges in accessing ART (OR = 19.21; 95% CI: 2.54–145.57; p = 0.004) were also associated with higher odds of poor HIV treatment outcomes, although this last estimate was based on a very small number (n=19) out of all 356 observations.

Table 4.14: Unadjusted associations for intermediate variables in the pathway between water insecurity and HIV treatment outcomes (N= 356)

Intermediate	N (%) / Mean (SD)	WI → Intermediate (Effect, 95% CI)	p-value	Intermediate → HIV outcomes (Effect, 95% CI)	p-value
ART access challenges (yes)	19 (5.3%)	OR = 1.56 (0.51–4.82)	0.440	OR = 19.21 (2.54–145.57)	0.004
Food insecurity score	14 (6.8)	β = 5.44 (3.99–6.89)	<0.001	OR = 1.09 (1.06–1.13)	<0.001
Depression score	4.9 (4.1)	β = 1.89 (0.96–2.82)	<0.001	OR = 1.17 (1.10–1.24)	<0.001
Anxiety score	5.9 (4.2)	β = 2.05 (1.11–2.99)	<0.001	OR = 1.11 (1.05–1.17)	<0.001
Water-related illness (yes)	316 (88.8%)	OR = 5.09 (2.55–10.13)	<0.001	OR = 2.36 (1.17–4.74)	0.016

***Values are presented as n (%) for categorical variables, and mean (SD) for continuous variables. Effect estimates are from separate unadjusted regression models, with β coefficients reported for continuous and odds ratios for binary outcomes.**

4.6 The Novel Conceptual Model

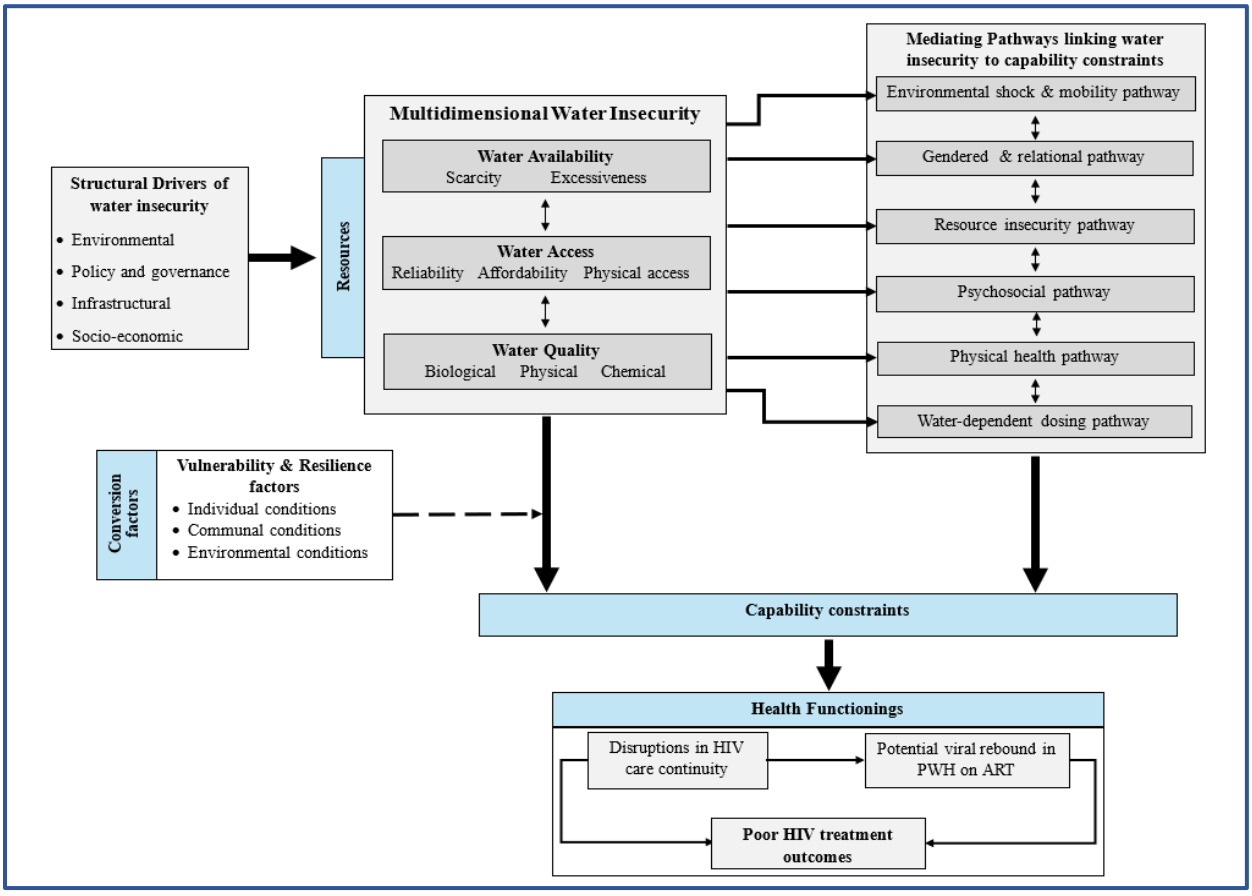


Figure 4.7: A novel conceptual model of pathways from water insecurity to HIV treatment outcomes among adults on ART

Structural drivers shown on the left determine the nature of multidimensional water insecurity, which is operationalized in this model through the dimensions of availability, access, and quality. These dimensions may influence HIV health either directly or indirectly. They also trigger a set of interconnected mediating pathways that can affect HIV health individually or in combination. Importantly, vulnerability and resilience factors operating at the individual, community, and environmental levels may either buffer or exacerbate individuals' abilities to convert available resources into health-seeking capabilities. Together, the direct and indirect effects of water insecurity (shown by the long downward facing arrows) create capability constraints, such as the inability to maintain adequate hygiene, access safe water, or adhere to prescribed medication schedules. These capability constraints ultimately limit the achievement of desired health functionings among adults receiving antiretroviral therapy by disrupting continuity of HIV care, increasing the risk of viral rebound, and contributing to poor HIV treatment outcomes.

CHAPTER FIVE: DISCUSSION

In this chapter, the findings generated from the study are discussed, providing an integrated interpretation through comparison across data sources, triangulation of qualitative and quantitative evidence, and engagement with existing literature to contextualize the results. Portions of the interpretations and conclusions presented here have contributed to peer-reviewed publications (Odak, Murnane, et al., 2026; Odak, Young, et al., 2026) arising from this work. Any overlap reflects dissemination of the same original findings, and all related publications are appropriately acknowledged.

This study presents the first comprehensive and integrated assessment of water insecurity among adults on ART in Kisumu County. The study combines primary household survey data with environmental water sampling to offer a novel, multi-dimensional characterization of the socio-ecological drivers and dimensions of water insecurity, the lived experience of water insecurity by adults on ART and pathways from water insecurity to HIV outcomes, and the quantitative association between water insecurity and HIV treatment outcomes among adults on ART in a climate-vulnerable, high HIV burden, resource-limited setting.

5.1 Socio-ecological drivers and dimensions of water insecurity among adults on ART

The study sought to characterize the drivers and dimensions of water insecurity among 434 adult adults on ART in Kisumu County. This section begins by describing the sociodemographic characteristics of the participants in Kisumu County, which provides the contextual foundation for interpreting the prevalence, severity, perceived drivers and dimensions of water insecurity, the environmental water quality findings, and the individual- and community-level predictors identified in analytical models. In alignment with the SEM, water insecurity in this study was shaped by interacting influences across multiple levels of context.

5.1.1 Sociodemographic characteristics of adults on ART

From the findings of this study, adult women with HIV (WWH) on ART were disproportionately affected by water insecurity (78.9%), consistent with recent findings from Ghana (Nutor et al., 2024), but contradicting cross-country results from other LMICs that found similarity in water insecurity scores across sex (Young et al., 2022). Older adults appeared more vulnerable, possibly due to greater physical difficulties in managing water-related challenges. An equal median

household size for both water-insecure and secure groups indicates that socio-economic capacity to meet household water requirements, rather than just demographic metrics, drives water insecurity among adult adults on ART. These findings lay the foundation for understanding the distal or broader socio-ecological factors that create conditions that perpetuate water insecurity among adults on ART.

5.1.2 Prevalence and severity of household water insecurity

The findings demonstrate that water insecurity is both highly prevalent and severe among adults on ART in this study setting, confirming it as a significant yet often overlooked structural hardship. Nearly two-thirds of participants experienced household water insecurity, with a mean HWISE score of 16, meaning that the average respondent falls within the moderate range of water insecurity. The distribution of scores reveals that water insecurity was not only widespread but also intense, with most participants reporting moderate to high water insecurity. This severity gradient suggests that many adults on ART contend with frequent, compounding water-related hardships that likely extend beyond occasional scarcity, to sustained challenges in accessing water for daily needs. The mean water insecurity score observed in this study was substantially higher than the mean score of 5.9 reported in a comparable study among PWH in western Kenya (Nagata et al., 2021), likely due to that study's requirement of access to surface water for inclusion in the parent study sample. The extent and severe nature of household water insecurity observed in this sample points to underlying socio-ecological drivers that predispose adults on ART in this study context to water insecurity.

5.1.3 Perceived socio-ecological drivers and dimensions of water insecurity

Environmental stressors were prominent perceived drivers of water insecurity in this population, with drought consistently reported as disrupting access to reliable and safe water. The emphasis on droughts and floods shows their visible and immediate effects on water sources and accessibility, not only due to the seasonal bi-annual flooding and intervening dry periods that have long characterized the study area, but also possibly because of the effects of climate change. These effects are depicted by increase in the frequency and intensity of these EWEs, often resulting in emergency-level devastation in addition to creating conditions for water insecurity. The findings from this study reinforce evidence linking EWEs to water scarcity and overabundance across SSA (Achore & Bisung, 2023; Pienaah et al., 2024). Apart from weather-related determinants, spatial

disadvantages, including geographic location and topography further intensified the vulnerability of adults on ART to water insecurity, illustrating the intersection of environmental and geographic factors in shaping access to safe and reliable water.

Socio-economic barriers also emerged as important perceived drivers of water insecurity. Poverty likely limited the ability of households to purchase water or invest in storage; a finding echoed in Ghana (Achore & Bisung, 2023). Inadequate infrastructure was reported to constrain access, consistent with evidence from Colombia where infrastructural deficits were central to water insecurity (Lemaitre et al., 2023). These challenges reveal systemic failures in water provision and governance that disproportionately affect resource-limited populations in rural and semi-rural areas. The convergence of poverty and infrastructural inadequacies further demonstrates the interconnected nature of economic and physical access, suggesting that even when sources exist, they may remain inaccessible to resource-constrained households caught between poverty and ill health. High population density was perceived to exacerbate scarcity through competition for limited usable water. This finding aligns with prior studies linking population growth to water insecurity (Abubakr et al., 2021; Achore & Bisung, 2023), but goes further to demonstrate that in the context of the study area, it is competition for safe, usable water, rather than sheer population size or lack of water sources, that constrains access for adults on ART. Conflicts were not a salient driver of water insecurity in our context, unlike findings from other settings where water-related disputes are a prominent cause of water insecurity (Water Peace and Security, 2022; Wheatley, 2024). These differences highlight the importance of local context in shaping both the perception and reality of water insecurity.

Water insecurity was experienced through intersecting dimensions including availability, access, and quality. Respondents reported unstable availability, access barriers such as unaffordable costs, long distances to improved sources, unreliable supply, and inadequate household storage. Water quality also emerged as a critical dimension, with participants reporting perceived physical, microbiological and chemical contamination of sources. These findings align with prior work identifying unsafe water as a key driver of household water insecurity (Achore & Bisung, 2023; Ahuja, 2021; Emran et al., 2024; WWF-Kenya, 2024). The current study extends this evidence by conceptually linking these overlapping dimensions to heightened health risks for adults on ART, for whom unsafe water and unreliable access have direct consequences on hygiene, treatment

adherence especially through delayed and missed doses, and susceptibility to water-related illnesses.

5.1.4 Sociodemographic and community-level predictors of water insecurity

Analytically, key sociodemographic and community-level predictors that determined differential risk of water insecurity were identified in this study. The strongest independent predictors were female sex, household size, housing type, and household income, reflecting deeply embedded structural inequities. Sex emerged as the dominant predictor, with women having over threefold the odds of water insecurity compared to men. This disparity aligns with extensive evidence from LMICs showing that water collection responsibilities disproportionately fall on women (De Guzman et al., 2023; Pouramin et al., 2020; Tomberge et al., 2021; World Bank Group, 2024). Beyond these structural patterns, women face the compounded burdens of competing water-related time demands, physical strain, and psychosocial stressors (Kangmennaang et al., 2020b). For adult WWH on ART, these burdens intersect with health vulnerabilities and can undermine HIV treatment success.

Larger household size was also associated with greater water insecurity, likely due to increased daily water requirements that strain available water and the financial resources needed to secure supply. Similar findings from Ghana, Nigeria, and Ethiopia show that larger households struggle to meet daily water needs when supply is limited or distant (Oyerinde & Jacobs, 2022; Pienaah et al., 2024). For households affected by HIV, water demand may compete with other essential needs, further straining resources and limiting the ability to maintain consistent engagement in HIV care. Housing security also emerged as another determinant of water insecurity. Participants living in temporary or informal dwellings were more likely to experience water insecurity, consistent with studies that have linked housing type and water access in Kenya (Joshi et al., 2023; Njoroge et al., 2024). These findings highlight how infrastructure and structural poverty intersect to limit access to safe and reliable water.

Findings from this current study show that higher income is protective against water insecurity, reinforcing evidence that economic capacity enables households to purchase water from multiple sources, invest in water storage and treatment, and withstand price fluctuations (Zozmann et al., 2022). The observation that only households above certain income levels achieved meaningful reductions in water insecurity in this study supports evidence that marginal income gains rarely

translate to improved water security (Joshi et al., 2023; Njoroge et al., 2024; Stoler et al., 2020). For adults on ART, greater financial flexibility may also ease trade-offs between securing water and meeting other health-related expenses, thereby supporting both water security and treatment.

At the community level, long distances to water sources, microbial and chemical contamination were strong independent predictors of water insecurity. Microbial contamination had the strongest association with water insecurity, reflecting both perceived and actual threats of unsafe water to health, and may signal recurrent healthcare utilization among adults on ART for treatment of water-related infections. While less apparent, chemical pollutants pose long-term health risks for adults on ART already contending with compromised immune function (WHO, 2023b).

5.1.5 Microbiological and physicochemical quality of sources used by participants

From the water quality sub-study, laboratory tests confirmed that many water sources used by adults on ART and their households in Kisumu County are contaminated, confirming reports by participants about the physical, biological and chemical contamination of their water sources. Escherichia coli was detected in more than one-third of sampled water sources, indicating fecal contamination and the likely presence of waterborne pathogens. Similar contamination patterns have been documented in Kisumu's rivers and other water bodies, where human activities and poor waste disposal contribute to microbial pollution of local water systems (Ogola et al., 2023). For adults on ART, exposure to biologically contaminated water poses heightened health risks because immunocompromised individuals are more susceptible to opportunistic infections. Water-related diarrheal diseases can lead to and worsen dehydration, reduce nutrient absorption, and interfere with antiretroviral therapy effectiveness, potentially contributing to poorer HIV-related health outcomes as previous studies have confirmed (Nagata et al., 2021).

Physicochemical results also revealed important patterns in water quality. Turbidity was the most frequently exceeded parameter in the present study, indicating reduced water clarity and potential sediment loading in several sources. Comparable elevations in turbidity have been reported in water sources in Kisumu's informal settlements and peri-urban environments (Othoo et al., 2020). In those settings, high turbidity has been associated with rainfall-driven runoff and flooding that transport sediments and contaminants into shallow wells and other surface water sources like rivers and Lake Victoria. The turbidity levels observed in the present study therefore align with these

findings and suggest that seasonal hydrological processes may contribute to sediment transport and reduced water clarity in local water sources used by adults on ART in the study area.

Other physicochemical parameters further reflected the influence of both natural and anthropogenic processes based on the water quality results. Elevated bicarbonate concentrations observed in several samples indicate mineralization of groundwater sources, a pattern consistent with hydrogeochemical studies showing that groundwater in the Kisumu aquifer system is influenced by water and rock interactions and dissolution of carbonate minerals (Kanoti, 2021). In addition, elevated nitrate and ammonium concentrations detected in some samples suggest possible contamination from wastewater discharge, agricultural activities, or nearby sanitation systems. Similar groundwater contamination patterns have been documented across the Lake Victoria Basin, where shallow wells frequently exceed nitrate limits due to sewage infiltration and poorly managed sanitation infrastructure (Nyilitya et al., 2021). Although concentrations of toxic metals remained largely within guideline limits, the coexistence of microbiological contamination and physicochemical exceedances indicates that households relying on unsafe water sources may be exposed to multiple environmental health risks simultaneously, which may further compound the vulnerability of adults on ART in resource-limited settings (Nyanza et al., 2024). As an example, elevated sulfate concentrations in drinking water may cause gastrointestinal irritation and laxative effects, which can contribute to dehydration and reduced nutrient absorption (WHO, 2022b), outcomes that may be particularly concerning for adults on ART, with serious implications for treatment outcomes.

While these findings address the first study objective by identifying the prevalence and socio-ecological determinants of water insecurity among adults on ART in Kisumu County, they do not fully communicate how these constraints are experienced, negotiated, and embodied in daily lives of those adults on ART, such that being exposed to water insecurity might influence their HIV health. Building on this structural and analytic understanding, the next section addresses the second objective by exploring the lived experiences of water insecurity and the pathways through which it shapes health and wellbeing of adults on ART in Kisumu County.

5.2 The lived experience of water insecurity and pathways to HIV treatment outcomes

A qualitative exploration of the lived experiences of water insecurity by adults on ART in Kisumu County was conducted and the findings used to develop a conceptual framework, anchored on Amartya Sen's capability framework, of the pathways from water insecurity to HIV treatment outcomes. Eight interrelated themes were identified, which demonstrate that water insecurity among adults on ART is not experienced as a hardship based on isolated acute episodes, but as a chronic, multidimensional condition shaped by determinants in the natural, social, and built environment. From this study's findings, water insecurity permeates almost every aspect of daily lives of adults on ART and is embedded in their routines and decision-making. It creates continuous physical, psychosocial, and economic strain that constrain health, dignity, and ability to sustain uninterrupted HIV care continuity in a high HIV burden setting.

5.2.1 The lived experience of water insecurity among adults on ART

Environmental factors, including extreme weather, predispose adults on ART in Kisumu County to water insecurity. In particular, living in low-lying areas near large surface water bodies is central to the experience of water insecurity. Recurrent flooding, prolonged dry seasons, and increasingly unpredictable weather patterns expose adults on ART to alternating water scarcity and excessiveness, and to contaminated sources under both conditions, thus affecting the daily life survival needs, activities, and health of adults on ART. This finding aligns with a study conducted in Kenya on interruptions to HIV care due to natural disasters (Tran et al., 2023), and another study showing that EWEs are associated with poor HIV outcomes, with water insecurity comprising a mechanistic pathway from climate change and EWEs to HIV outcomes (Logie & MacNeil, 2024). However, the findings contrast with a recent study that emphasized social determinants, framing water insecurity primarily as the product of human behavior (Wutich, 2025). The divergence is likely due to contextual differences, since environmental factors in the study area play an important role in limiting reliable access to water.

Limited access to adequate and safe water is a dominant lived experience, characterized by long distances to usable water sources, unreliable supply, and unaffordable costs. Access challenges force adults on ART into physically demanding, at times risky efforts to get water; efforts that displace time from clinic visits, ART adherence, self-care, and livelihood activities due to competing water collection demands. The access difficulties identified in this study resonate with

emerging evidence from Kenya, Ghana, Nigeria, and Zambia that have documented how distance, time displacement, and cost restrict households to water quantities below the daily recommended standards (Collins et al., 2019; Hamill et al., 2023; Krumdieck et al., 2016; Nutor et al., 2024; Owuor et al., 2024). This finding on poor access triangulates with results from the first objective, which identified long distances and unaffordability as access factors contributing to water insecurity among adults on ART in Kisumu County. Importantly, the lived experience data show how these access constraints, apart from limiting water for daily requirements, translate into routine trade-offs that directly undermine HIV care engagement.

In this study, it emerged that water insecurity intensifies reliance on unsafe water sources, exposing adults on ART to water-related illnesses including diarrhea, typhoid, bilharzia, malaria, and skin infections. Reports of recurrent episodes of financially burdensome illnesses not only exacerbates HIV health challenges, but also points to increased healthcare utilization, including out-of-pocket expenditures for treatment. This finding concurs with evidence from Kenya and other LMICs that show the disproportionate vulnerability of adults on ART to waterborne infections due to compromised immunity, often leading to recurrent morbidity, nutritional stress, and multiple clinic visits. For example, a recent study conducted among adult PWH (Miller et al., 2021a) and a previous systematic review (Yates et al., 2015) in western Kenya found associations between water insecurity and diarrheal diseases. The lived experience presented here demonstrates how poor water quality affects the health and well-being of adults on ART, reducing the body's physical functioning. Further, this study strengthens existing evidence through triangulation with findings on the dimensions of water insecurity and laboratory analyses of water samples; confirming microbiological contamination of some communal sources used by adults on ART in Kisumu County, as indicated by the presence of total coliforms and E-coli.

Entrenched gendered norms and water-related violence emerged as a critical lived experience of water insecurity that severely constrained the capabilities of adult WWH. This study found that deep-rooted cultural norms was an enabler of gendered division of labor that positioned water collection as the duty and responsibility of WWH, forcing them into long, risky, and unpaid labor. In addition, they experience violence during water collection or at home when household expectations are unmet, illustrating how gender norms shape the burden of water collection, placing women at the center of household water management despite the risks and challenges involved. This evidence supports findings from other contexts in LMICs which have documented

water-based gender violence (Ahmed et al., 2021; De Guzman et al., 2023; Pouramin et al., 2020; Tallman et al., 2024; West et al., 2013). The current study extends this literature by explicitly situating water-related violence within the context of HIV treatment interruptions, elucidating how fear, household power imbalance, and relational conflict disrupt the stability, physical, and emotional security required for consistent HIV treatment engagement and outcomes.

Frequent displacement by floods is another salient lived experience of water insecurity that causes disruptions in the lives of adults on ART, affecting their property, livelihood activities, and health. The sudden onset of flood disasters compounds the daily challenges faced by adults on ART, who must work harder to not only stay alive, but avoid situations that can jeopardize their HIV health. These experiences are consistent with findings from Namibia and other flood-prone regions showing that flooding affects the daily lives of PWH (Anthonj et al., 2015). Due to floods, adults on ART are faced with an additional precarity of having to flee their homes, often to schools, churches or rescue centers that are ill-equipped to provide privacy, comfort and reasonable amenities. Survivors' routines are disrupted, and their capabilities for everyday life activities, including eating, sleeping, hygiene, sanitation, and importantly, medication adherence in these overcrowded facilities are diminished; often with no knowledge of how long they have to stay there, and no clear plans of rebuilding their lives after floods.

The loss of livelihoods and food crops due to water insecurity deepens economic strain for adults on ART who are already under-resourced. Besides periodically losing their livelihoods, these adults on ART experience food insecurity as a co-occurring lived experience, resulting from the loss of crops to drought or flooding, but also because of diminished earning opportunities, especially those engaged in small-scale agricultural activities. The resulting economic strain limits purchasing power and exacerbates vulnerability to food insecurity. Together, economic deprivation and food insecurity directly determine HIV care decisions.

Psychosocial distress is another prominent lived experience of water insecurity by adults on ART that cuts across all the other lived experiences in this study. Participants described chronic stress, worry, anxiety, sleeplessness, hopelessness, and mental exhaustion tied to unpredictable access to water, to risks posed to life, health, livelihood activities, food, and property. This finding mirrors growing evidence that water insecurity is strongly associated with anxiety and depression in PWH (Miller et al., 2021a), particularly among WWH, whose emotional burdens are exacerbated by

gendered household responsibilities, and with evidence linking climate-related stressors to emotional well-being among PWH in Kenya (Beyeler et al., 2023). The current study adds to existing literature by elucidating how psychosocial distress accumulates from intersecting water-related hardships, progressively eroding the emotional and cognitive resources that adults on ART require to sustain HIV care.

The finding that water insecurity directly disrupts HIV treatment engagement and continuity is perhaps the most profound lived experience of water insecurity among adults on ART. In this study, five mechanistic pathways through which this could occur were identified. First, the shortage of potable water during scheduled times for taking medication leads to delayed or skipped doses despite having the pills. Another reason for delayed or missed doses is flood-induced displacement. Second, adults on ART are sometimes forced to miss scheduled clinic visits for refills and viral load checks due to water-related challenges. This study unravelled how missed clinic visits led to consequences that were mostly counterproductive: health service providers, in a bid to enforce adherence, would give drugs for shorter time periods, but the increased requirement for trips to the clinics proved cumbersome and even untenable for many clients, leading to even more missed doses. Third, the co-occurrence of water and food insecurity was another mechanistic pathway, as evidenced by a study on the intersection between the two insecurities (Frongillo, 2023). Multiple studies have shown the syndemic relationship between these two resource insecurities and HIV outcomes, mostly due to adherence challenges, but also due to undernutrition. Fourth, when there is frequent non-adherence, PWH can experience sub-optimal viral suppression as has been shown in a previous study conducted in Kenya (Nagata et al., 2021) and another among pregnant and postpartum women in Ghana (Nutor et al., 2024). The current study extends this existing evidence by further unpacking how non-adherence due to water insecurity is linked to viral rebound in adults on ART. This finding was confirmed in the case-control study, where water insecurity was associated with over 3 times the odds of poor HIV treatment outcomes. This level of evidence (from the case-control study) provides a strong rationale to proceed to an RCT to test targeted interventions.

5.2.2 Pathways from water insecurity to HIV treatment outcomes

While the lived experiences discussed above show the breadth and depth of water insecurity in the daily lives of adults on ART, they also elucidate how those experiences translate into specific

mechanistic pathways through which water insecurity constrains capabilities so as to compromise HIV treatment engagement and outcomes for adults on ART. Interpreted through the capability framework, the documented constraints on physical functioning, emotional well-being, social safety, economic stability, and daily routines do not only coexist, but also interact in ways that progressively narrow the real freedoms required by adults on ART to sustain uninterrupted HIV care engagement. Importantly, these lived experiences show that the relationship between water insecurity and HIV health is not a single, linear mechanism. Rather, water insecurity operates through multiple, interrelated pathways that converge to constrain the capabilities of adults on ART, converting environmental and structural factors into individual-level disruptions in daily functioning and continuity of HIV care. For example, constrained access to adequate water, exposure to unsafe water, and flood-induced displacement from settlements interfere with adherence to medication and clinic visits. Economic losses, food insecurity, GBV, and psychosocial distress act as reinforcing conditions that further erode the capacity to adhere to ART. Such interdependencies show that HIV treatment disruptions do not just arise from isolated behaviors, but also from cumulative capability deprivations driven by water insecurity. Building on these lived experiences, the following section illustrates key mechanistic pathways through which water insecurity undermines HIV treatment engagement and outcomes among water insecure adults on ART.

Environmental shocks and mobility pathway

In this study, it was found that environmental shocks and mobility constitute a pathway from water insecurity to HIV treatment outcomes, similar to findings from a study which showed relationships between climate change and HIV/AIDS (Lieber et al., 2021). EWEs like flooding are a threat to vulnerable populations and can force adults on ART into emergency displacement. Such displacements destabilize living conditions, cause losses to property and loss of medication especially when adults on ART have to immediately evacuate in the night. Additionally, floods damage infrastructure which limit access to health facilities, which can also become inaccessible due to inundation by floods. As opposed to happening as episodic events, these EWEs create periods of instability during which the capability to maintain uninterrupted care engagement is severely constrained. This pathway, which also holds true for periods of drought when adults on ART move in search of water, is concurrent with evidence from a systematic review on drought and ART adherence in Africa (Orievulu et al., 2020); and shows how environmental shocks

operate beyond immediate water access challenges to disrupt settlement stability, access to health services, and the ability to sustain treatment engagement.

Resource insecurity Pathway

Water insecurity also operates through resource insecurity pathways by constraining access to food, income, and livelihood opportunities that are essential for sustaining HIV care. Consistent with extensive evidence from SSA, this study identified food insecurity as a mechanistic pathway from water insecurity to HIV outcomes. Water insecurity limits the capability for adequate nourishment by undermining food production, preparation, and purchasing power, thus reducing dietary quantity and quality. Previous research has demonstrated strong associations between food insecurity and poor HIV outcomes including non-adherence and viral non-suppression (Aibibula et al., 2017; Weiser et al., 2011; Young et al., 2014).

Findings from this study reinforce the syndemic nature of resource insecurities in shaping HIV health but also contribute to existing knowledge by positioning food insecurity as a downstream manifestation of multidimensional water insecurity that mediates its association with HIV outcomes, rather than as an isolated determinant that co-occurs with it. Economic losses due to disrupted livelihoods, combined with reduced food availability, limit the capacity to meet the needs that can support treatment, such as adequate nutrition and transport to health facilities.

By centering lived experience, these findings show that water insecurity not only reduces food access, productive engagement in livelihood activities, and ability to take medication comfortably, but it also creates trade-offs that undermine adherence and care engagement. This integrated interpretation highlights that interventions targeting food insecurity or income generation alone may be insufficient to support HIV treatment continuity unless the upstream water constraints that erode nutritional and livelihood capabilities are simultaneously addressed.

Gendered and relational pathways

From the findings of this study, water insecurity also operates through gendered and relational pathways that constrain safety, agency, and social stability especially among adult WWH. Entrenched gendered norms that assign household water collection and management to women disproportionately expose the WWH to physical burden, danger, emotional strain, reduced autonomy, and IPV when water is scarce or when the role expectations are not met. These findings

demonstrate that water insecurity works as a trigger for IPV and relational conflict, rather than merely co-occurring with it, consistent with cross-cultural evidence that has documented water-related GBV (Cole et al., 2024; Tallman et al., 2023, 2024).

In concurrence with prior findings, water insecurity is associated with increased risk of IPV among adult WWH, which has been linked to missed clinic visits, antiretroviral non-adherence, and treatment interruption (Odak, Young, et al., 2026)**.** In the current study, water insecurity explicitly links these gendered and relational dynamics to disruptions in HIV treatment continuity, showing how emotional distress and relational instability such as fleeing marital homes due to fear of violence or being forcefully sent away by spouses interfere with medication adherence and clinic attendance for water insecure adult WWH. This means therefore, that disruptions in HIV care are not only driven by individual patient behavior, but also by socially mediated power relations and imbalances that undermine capabilities related to bodily integrity, personal security, and decision-making autonomy, thus constraining the real freedoms that adult WWH on ART have so as to protect their health and sustain HIV treatment.

Psychosocial pathways

Water insecurity is also linked to HIV treatment engagement and outcomes via psychosocial pathways that constrain emotional well-being, cognitive functioning, and the capacity to sustain care-related routines. Chronic uncertainty surrounding water access, fear of flooding, recurrent illnesses, economic strain, GBV and IPV risks, and threats to personal safety generate chronic stress, anxiety, mental exhaustion, sleeplessness, hopelessness, and forgetfulness, which, interpreted from the capability framework lens, work to diminish motivation, concentration, attention, and memory required to maintain consistent ART adherence and clinic visits. These findings resonate with a growing body of literature that has documented strong links between water insecurity and psychological distress among PWH in LMICs (Boateng et al., 2022; Collins et al., 2019). Prior studies have also shown that such psychological distress is linked to poorer ART adherence and care engagement (HIV/AIDS & Psychology, 2025; Nyongesa et al., 2022). Findings from the current study advances this literature by demonstrating how psychosocial distress emerges cumulatively from intersecting water-related hardships rather than as a standalone mental health outcome, and that sustained emotional strain progressively erodes cognitive and emotional capabilities essential for HIV self-management.

Physical health pathways

Beyond the psychosocial effects, water insecurity undermines HIV treatment engagement and outcomes through physical health pathways that work by constraining individuals' functional capacity. Reliance on unsafe water sources, for example, exposes adults on ART to water-related illnesses. For adults on ART, recurrent illnesses represent more than transient morbidity since they weaken physical functioning, increase health-related expenditures, and disrupt daily routines necessary for sustaining HIV care. In this sense, rather than reiterating the lived experience of illness, these findings show how recurrent morbidity emerges as a capability constraint that limits the energy and physiological stability required for adherence and clinic engagement.

Findings from this study adds to existing evidence already cited earlier by situating physical illness as a mechanistic pathway within a broader capability framework, demonstrating how compromised bodily health diminishes the energy, strength, and physiological well-being that adult PWH require to adhere to ART, attend clinic appointments, and engage in livelihood activities that can help support uninterrupted treatment continuity.

Water-dependent dosing pathways

A critical and more proximal pathway identified in this study is the water-dependent dosing pathway, where lack of water at the time scheduled for taking medication directly prevents adherence. Despite having access to medication, adults on ART encounter situations in which they are unable to swallow pills due to lack of water or prepare food required to support ART use, leading to delayed or skipped doses. Unlike other pathways that operate through cumulative constraints, this pathway reflects an immediate, point-of-use barrier to adherence. Over time, these repeated disruptions contribute to intermittent adherence and treatment interruption, linking structural water constraints directly to HIV treatment outcomes.

Coping and adaptation pathways for such situations encompass both protective responses like taking ARVs without water but on time, and maladaptive responses like delaying doses, meal skipping, fewer meals per day, smaller portions per meal, unsafe water use, delaying clinic visits, or temporarily interrupting ART. While these strategies for prioritizing immediate survival needs may seem maladaptive from a clinical lens, they represent rational responses to severely limited capabilities. However, the interruption of treatment even for short periods is associated with rapid drop in CD4 cell count, rise in viral load, and risk of progression to AIDS (Panel on Antiretroviral

Guidelines for Adults and Adolescents, 2025). This study contributes to existing literature by demonstrating that coping strategies among adults on ART are structurally produced by multidimensional water insecurity and its intersecting pathways rather than arising from non-compliance by individual patients.

5.3 The association of water insecurity with HIV treatment outcomes

In this novel case-control study, evidence is provided to show that water insecurity is a strong, important, and independent predictor of poor HIV treatment outcomes among PWH that persists even after controlling for other covariates. This finding reframes it from a background material hardship to a central structural determinant of HIV treatment vulnerability. This study demonstrates that its effects on treatment success persist beyond socioeconomic and health system factors by providing the strongest quantitative evidence to date that links it to poor treatment outcomes among adults on ART in a high-prevalence, climate-vulnerable region. In Kisumu County, water insecure adults on ART had close to four times higher adjusted odds of poor HIV treatment outcomes, a finding that illuminates the clinical and public health significance of this association in a real-world setting of chronic resource and environmental stress.

The persistence of the association between water insecurity and HIV treatment outcomes after adjustment indicates that this relationship is not explained by demographic characteristics, socioeconomic position, food insecurity, or facility-level differences alone. This progression from a strong unadjusted association (OR ≈ 3.2) to an even larger adjusted effect (AOR ≈ 4.0) suggests negative confounding by socio-structural and clinical factors, reinforcing water insecurity as a fundamental driver of treatment vulnerability rather than a proxy for poverty alone. These findings are consistent with prior research linking water access challenges to poor HIV treatment outcomes (Boateng et al., 2022; Nutor et al., 2024). The findings also triangulate with those of the qualitative study which identified multiple pathways linking water insecurity to treatment disruption. The quantitative association observed in this case-control study provides empirical confirmation of those pathways. The near four-fold increased odds of poor outcomes reflect the cumulative effect of these lived disruptions. Thus, the association demonstrated here is not mechanistic abstraction; it is grounded in documented experiential realities.

These findings extend prior literature that has predominantly focused on food insecurity as a key structural barrier to HIV treatment adherence and viral suppression. The continued strength of the water insecurity association after controlling for known confounders indicates that water insecurity operates through additional and distinct pathways. This aligns with emerging studies from SSA documenting how water scarcity, long collection times, and poor water quality directly interfere with medication-taking and contribute to poor HIV treatment outcomes. For example, a study conducted in Kenya among adult PWH enrolled in a food insecurity intervention trial found a baseline association between water insecurity and sub-optimal viral suppression as well as opportunistic infections (Nagata et al., 2021). Another study conducted in Ghana found that household water insecurity was associated with poor ART adherence and increased psychosocial distress among pregnant and post-partum women (Nutor et al., 2024). However, few studies have quantified this relationship, positioning this work as an important extension of existing evidence.

The findings also indicate a statistically significant association between duration of ART and increased odds of poor HIV treatment outcomes, with each additional year on treatment associated with a 5% rise in the odds of unsuccessful treatment outcomes. This finding is in concurrence with those of a study conducted in Ethiopia among children with HIV which identified prolonged ART duration as a critical predictor of treatment failure (Getawa et al., 2021). While ART initiation is typically linked to improved viral suppression and clinical recovery (Panel on Antiretroviral Guidelines for Adults and Adolescents, 2025), prolonged treatment exposure may introduce new vulnerabilities over time. In addition, long-term ART use may result in cumulative toxicities, including metabolic or renal complications, which can further compromise overall health and treatment tolerance (Spach, 2025). In resource-constrained settings such as Kisumu County, chronic exposure to water and food insecurity, financial strain, and competing survival priorities may progressively erode adherence capacity over the life course. Notably, because age and sex were matching variables and did not demonstrate independent associations in multivariable models, duration of ART emerges as a key independent correlate of poor outcomes in this cohort. Together, these findings underscore the importance of sustained monitoring, differentiated long-term adherence support, and timely regimen optimization to mitigate the risks inherent in lifelong HIV therapy.

Facility-level differences observed across clinic sites further emphasize the importance of contextual factors in HIV care. The lower odds of poor outcomes among participants attending

Kombewa clinic after adjustment suggest variation in service delivery, patient support mechanisms, or surrounding environmental conditions. Adjusting for clinic site strengthened the internal validity of the analysis and supports the methodological decision to account for imperfect matching through site fixed effects rather than conditional regression.

This study found a strong association between the severity of water insecurity and HIV treatment outcomes among adults on ART. Similar to the study by Nagata et al., (2021) conducted in western Kenya, and the Ghana study by Nutor et al., (2024), participants experiencing higher levels of water insecurity in the current study had substantially greater odds of poor treatment outcomes, with the magnitude of risk increasing with severity. Those experiencing 'high' water insecurity had markedly elevated odds of poor HIV treatment outcomes compared with those experiencing 'no - marginal' water insecurity. The large magnitude of this estimate reflects the concentration of cases relative to controls in the 'high' water insecurity category, indicating that severe water insecurity was disproportionately experienced among participants with poor treatment outcomes. The observed gradient across categorical and continuous water insecurity models indicates a clear dose–response relationship between increasing water insecurity severity and adverse HIV treatment outcomes. These quantitative patterns align with participants' lived experiences.

From the findings of the case-control study, there was no statistical evidence that sex modified the association between water insecurity and HIV treatment outcomes, showing that once water insecurity occurs, treatment outcomes become broadly similar across males and females. The observed convergence of predicted probabilities among water-insecure males and females suggests that while gender differences may influence baseline vulnerability under water-secure conditions, water insecurity may narrow those differences, resulting in comparable HIV treatment outcomes across sexes.

Although the interaction between water insecurity and sex was not statistically significant, the pattern of predicted probabilities suggests potential gendered differences in how water insecurity affects treatment outcomes. This interpretation aligns with qualitative findings from the study, where women described both heightened water-related burdens and adaptive strategies that may partially buffer the clinical consequences of water insecurity, while men more often reported disengagement from care under conditions of resource stress. These findings suggest that gender may shape how water insecurity is experienced and managed, even if the overall effect on HIV

treatment outcomes appears similar across sexes. The lack of statistical evidence for interaction likely reflects limited statistical power to detect effect modification as opposed to the absolute absence of meaningful gendered effects, and points to an important area for future research.

Crucially, these quantitative findings triangulate closely with the first two objectives of this study. Objective 1 characterized the determinants and dimensions of water insecurity, including unreliable access and poor water quality, while Objective 2 documented water insecurity as a chronic, multidimensional lived experience shaped by structural constraints. Together, these findings provide plausible mechanisms for the observed association between water insecurity and HIV treatment outcomes. The integration of determinants, mechanistic pathways, and epidemiologic associations in this study advances understanding of water insecurity as a structural determinant of HIV treatment outcomes and provides a strong empirical foundation for developing integrated interventions that address water access and quality as part of comprehensive HIV care in climate-vulnerable settings.

Overall, findings from this study demonstrate that water insecurity extends beyond a social condition of inadequate access to water, and can more accurately be understood as a dynamic and structurally produced phenomenon shaped by both scarcity and excess, access challenges, and water safety concerns. It emerges from broader structural conditions (including environmental factors, infrastructure, governance, and socioeconomic inequalities), and operates through cascading pathways at the community, household and individual levels. Evidence from this study further shows that disruptions in water availability, access, and quality interact to constrain capabilities and undermine the achievement of essential functionings, including those necessary for maintaining overall health and well-being.

These insights move beyond existing conceptualizations that emphasize deficits alone, and foreground instability in water availability, structural conditions that shape access and quality, and lived experience as central to water insecurity. Accordingly, this study advances the following water insecurity definition:

Water insecurity is a multidimensional structural condition arising from challenges with water availability (scarcity and excess), access, and quality, which constrain individuals' capabilities and limit the achievement of essential functionings necessary for overall physical, mental. And social health and well-being.

5.4 Limitations

1. The cross-sectional design of the first analytical objective precludes causal inference, limiting our ability to determine the directionality of observed associations between sociodemographic factors and water insecurity. However, this was partially addressed by situating findings within existing literature and by triangulating with qualitative data to support plausible temporal linkages. Although the sample was representative of adults on ART in the study sites, findings may not be generalizable to other regions with different water systems or socio-cultural contexts. This study however provided detailed contextual descriptions of the study setting and population to enhance transferability. Reliance on self-reported measures may have introduced reporting or recall bias, but this was mitigated using cross-culturally validated tools with bounded recall times and strained interviewers. Since fieldwork was conducted during the short rains and early dry season, findings may not reflect seasonal variation in water insecurity across the full annual cycle, however, efforts were made to capture variability in water experiences through diverse participant sampling and triangulation with qualitative accounts.

2. The lived experience findings should be interpreted in light of several limitations. The qualitative sample was purposively drawn from adults on ART engaged in HIV care and may not reflect the experiences of individuals who are disengaged from care or lost to follow-up, who may experience more severe forms of water insecurity. To partially address this, diverse participant groups and contexts were included to capture a wide range of lived experiences. Second, the study relied on self-reported narratives, which may be influenced by recall and social desirability bias, especially for sensitive experiences discussed in group settings. This was addressed through the use of experienced facilitators, careful moderation of discussions, and triangulation between IDIs and FGDs. Finally, while the study identified pathways linking water insecurity to HIV treatment disruptions, these pathways reflect perceived and experiential mechanisms rather than directly observed or longitudinally verified causal effects; however, integrating qualitative insights with quantitative findings strengthens the credibility and plausibility of the identified pathways.

3. The case–control findings should also be interpreted in light of several limitations. Although cases and controls were drawn from the same study base/source population and were matched

on age, sex, and time on ART, residual confounding was still possible, particularly for factors that may lie on the causal pathway or unmeasured confounders like polypharmacy or co-medication with cotrimoxazole to prevent infections. Residual confounding was minimized through adjustment of the matching variables and other key confounders in multivariable analyses. In addition, participants were further screened for existing or recently treated infections to ensure there was no misclassification of outcome based on the case definition. Second, water insecurity was assessed based on self-reported experiences, which may be subject to recall bias and non-differential misclassification of the exposure among both cases and controls. Such misclassification could have made the two groups more alike and biased the results towards the null. However, that means that the reported association is likely to be an underestimation of the true association between water insecurity and HIV treatment outcomes and does not affect the conclusions. Rather, it probably reinforces the conclusions of the study that water insecurity significantly increases the odds of poor HIV treatment outcomes. Finally, because participants were recruited from public health facilities, the findings may not be generalizable to adult PWH who are disengaged from care or receiving services outside the public health system. However, recruiting from routine care settings enhances the relevance of findings to programmatic HIV care contexts.

CHAPTER SIX: CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

6.1 Conclusions

Water insecurity among adults on ART in Kisumu County is a severe, multidimensional, and socially patterned phenomenon driven by intersecting environmental, infrastructural, and socio-economic factors. These drivers manifest through experiences of limited availability, constrained access, and compromised water quality, with vulnerability amplified by poverty, gendered roles, housing conditions, and environmental stressors. The findings demonstrate that water insecurity is not merely an environmental or infrastructural challenge, but a structural condition with important implications for HIV care continuity and wellbeing. Addressing water insecurity among people living with HIV will therefore require integrated, climate-responsive, and multisectoral approaches that combine water infrastructure investments, social protection, and HIV service delivery interventions.

Water insecurity is a pervasive lived experience among adults on ART that affects daily survival, health, and personal safety. It operates through multiple, interconnected, and potentially modifiable pathways that constrain individual capabilities and undermine sustained engagement in HIV care. These findings demonstrate that disruptions in HIV treatment continuity arise not solely from individual behaviors, but from cumulative capability deprivations rooted in broader structural, social, and environmental conditions.

Water insecurity is a strong and independent predictor of poor HIV treatment outcomes among adults on ART in Kisumu County. After accounting for key socio-demographic and clinical factors, individuals experiencing water insecurity had substantially higher odds of unsuccessful treatment outcomes. The absence of significant effect modification by sex suggests that the detrimental effects of water insecurity extend across gender groups, although this finding should be interpreted cautiously given limited statistical power to detect interaction effects. Taken together with the findings on determinants and lived experiences, the results provide convergent evidence that water insecurity is not peripheral to HIV care, but a central structural determinant of treatment continuity and clinical stability.

6.2 Recommendations

1. Because of the multidimensional nature of water insecurity, the County Government of Kisumu should strengthen multisectoral coordination among the health, water, environment, infrastructure, and social protection sectors to address the structural and environmental drivers of water insecurity as well as the social and economic vulnerabilities that mediate exposure and susceptibility to water insecurity, especially poverty and limited adaptive capacity. Investments should prioritize equitable expansion of reliable and climate-resilient water infrastructure in underserved communities, while integrating social protection interventions to mitigate the impacts of poverty and other upstream determinants that disproportionately affect PWH.

2. HIV implementing partners, such as the Center for International Health, Education, and Biosecurity (CIHEB-Kenya), should integrate water security interventions into routine HIV care and support services. This may include routine screening for water insecurity, targeted support for highly vulnerable households, provision of safe water treatment technologies and household water storage solutions, and the application of precision public health approaches to identify and support individuals at greatest risk of HIV care disruption due to water insecurity.

3. Given the magnitude and consistency of the association observed, the Ministry of Health, through the National AIDS and STI Control Programme (NASCOP), together with the National Syndemic Diseases Control Council (NSDCC), should integrate and institutionalize water security considerations within HIV care systems. This includes incorporating water security indicators into HIV monitoring, evaluation, and strategic planning frameworks, establishing referral pathways to water and social support services, and promoting multisectoral approaches that link HIV care, water access, and social protection systems to improve treatment continuity and long-term HIV outcomes among people living with HIV.

6.3 Suggestions for future research

1. Future research should examine further the broader structural and governance-related determinants of water insecurity, including water management systems, land use patterns, and institutional factors, using longitudinal designs to better understand how these drivers shape unequal access to safe and reliable water among adults on ART in climate-vulnerable settings.

2. A key area for future research is the development and evaluation of integrated interventions that address water insecurity as a structural barrier to HIV care. Specifically, integrated patient-provider studies using implementation science approaches should assess whether co-created interventions that improve reliable access to safe water among people living with HIV can enhance treatment adherence, reduce water-related illness, and improve HIV treatment outcomes in climate-vulnerable settings.

3. Future research should move beyond association to intervention testing. Randomized clinical trials (RCTS) are needed to determine whether improving household water security leads to measurable improvements in ART adherence, viral suppression, and mental health outcomes. Experimental or quasi-experimental designs evaluating integrated water–HIV interventions would strengthen causal inference. Additionally, future work should explore how climate-related extreme weather events intensify water insecurity and further destabilize HIV treatment continuity. Understanding the temporal dynamics and mediating pathways linking water insecurity to treatment disruption will be essential for designing scalable, sustainable, and climate-responsive HIV care models.

6.4 Summary statement of contribution made by the study

This study makes several important contributions to understanding the role of water insecurity in shaping HIV health outcomes among adults on ART in western Kenya. Foremost, the study makes a significant qualitative and a novel conceptual contribution by identifying and empirically grounding the mechanisms through which water insecurity disrupts HIV care. The study makes a significant qualitative contribution by documenting the lived experiences of water insecurity among adults on ART by foregrounding the voices of adults on ART, thus deepening understanding of not just how structural resource constraints are experienced and navigated in everyday life, but also how they translate into health outcomes.

Second, the study contributes conceptually by situating water insecurity within a broader socio-ecological framework and examining its determinants and dimensions, including availability, access, and quality. By identifying socio-ecological drivers such as poverty, inadequate infrastructure, environmental conditions, and climate-related stressors, the study highlights how water insecurity emerges from the interaction of structural and household-level factors. This

perspective advances conceptual understanding of water insecurity as a multidimensional determinant of health that intersects with broader systems of vulnerability affecting adults on ART.

Third, the study advances the existing literature base by providing robust quantitative evidence of the association between water insecurity and HIV treatment outcomes. Using a case–control study design, the research objectively examines the relationship between water insecurity and HIV treatment outcomes among adults on ART. This analytical approach strengthens causal inference by comparing individuals with different HIV treatment outcomes and assessing the extent to which water insecurity is associated with these outcomes.

Fourth, the study contributes methodologically by integrating multiple sources of evidence to examine water insecurity from both experiential and environmental perspectives. The research combines epidemiological analysis, qualitative narratives of lived experiences, and water quality assessments of commonly used water sources. This triangulated approach enables the study to link subjective experiences of water insecurity with objective measures of water contamination and access conditions, thereby providing a more comprehensive understanding of how water insecurity manifests and affects health.

In addition, the study provides baseline epidemiologic evidence by providing one of the first estimates of the prevalence of water insecurity among adults on ART in Kisumu County. Although water insecurity is increasingly recognized as an important social determinant of health, its magnitude among adults on ART in this region has not been previously quantified. By establishing the prevalence of water insecurity in a high HIV burden setting, the study fills a critical evidence gap and provides baseline data that can inform future research, policy, and programmatic responses.

Finally, the study makes important policy and programmatic contributions by generating evidence that can inform the design of integrated interventions addressing water insecurity within HIV care programs. By demonstrating the determinants, the mechanisms, and health implications of water insecurity among PWH in general and adults on ART in particular, the findings highlight the need for multisectoral responses that integrate HIV services with water, sanitation, and climate resilience strategies. The evidence generated by this study therefore provides a foundation for developing targeted interventions aimed at improving water access and supporting continuity of HIV care in climate-vulnerable settings.

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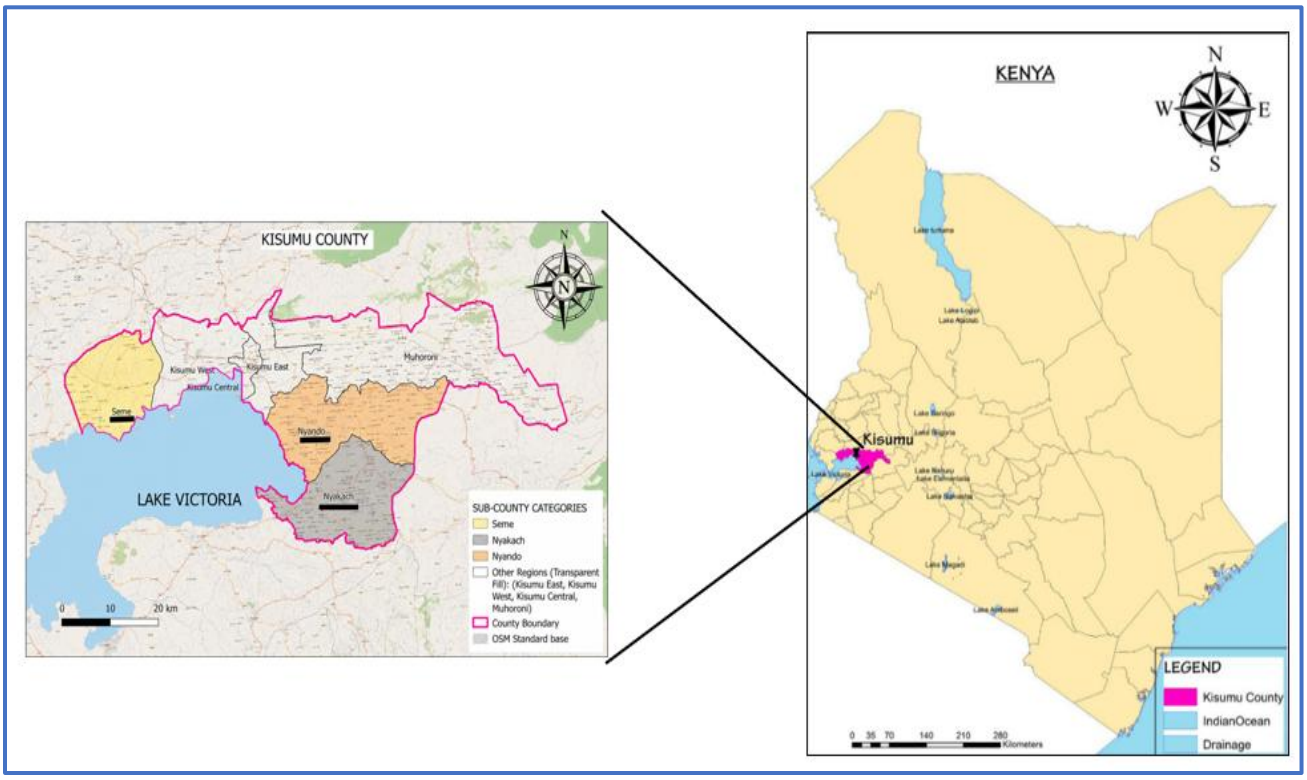
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APPENDICES

I. MAP OF STUDY AREA



II. INFORMED CONSENT FORM (ICF)

Note to Interviewer: Please use **"your child"** when administering the ICF to a parent/guardian of participants ages 15 – 17)

Introduction

Hello, my name is…….. I am a researcher and I have come to talk to you (your child) about a study we are conducting in this area on water insecurity and HIV. You are being approached to seek your permission to participate in this study because you are receiving care at the nearby Ahero/Nyakach/Kombewa County hospital where you access HTS services. Before you take part in this interview, we would like to give you details about the purpose, what is expected of you, risks, and benefits of participating in the study. We will give you a copy of this form to keep. Please ask questions if there is anything you do not understand or want clarified.

What is the purpose of the study?

We are conducting this research to better understand how problems associated with water, including access, affordability, scarcity, flooding, or contamination, may be affecting the health and well-being of adults on ART aged 15-64 in Kisumu County. Specifically, we would like to know the causes of these water problems in your area, your experiences with accessing clean water, income generating activities, production and access to sufficient food, settlement, mental well-being, retention in ART care, and how these issues may be affecting you and your health. We also want to know what can be done to reduce some of the problems of water insecurity.

What can you expect if you decide to take part in the study?

If you choose to participate in the study, you may be visited more than once by the research team. First, you will be asked to take part in a face-to-face interview today and possibly, in later phases of the study. You will be asked questions individually or in a group of adults on ART or both. Some questions will require you to talk about your experiences and will be audio-recorded to enable us to capture all the information you give us and will take about 1 hour. If you do not want to be audio-recorded, you cannot participate in those particular interviews. We may also obtain your clinical information from your health facility for use in the study. If we obtain your information, we will visit you again and inform you. Later, you may be approached to take part in a 4-month trial whose purpose is to find out whether treating water at home, having safe storage and information on safe water and hygiene practices can reduce the problem of water insecurity. Should you be selected to be part of this phase of the study, you will be informed and visited a few times to provide some information. At all times, your privacy and confidentiality will be upheld.

Are there risks if you decide to take part in this study?

The risks of joining this study are small. You may feel uneasy in answering questions about your health and other personal information, or to talk about your experiences in the presence of other people. You are free not to answer any question that makes you uncomfortable. There is a chance that your clinical information will be obtained but we will take care not to link it to your name. There is also a chance that someone could find out that you are participating in the study and see

your information, but we will take care to protect your privacy. You are free to choose a private location for any of the interviews. There is no cost to you to take part in this study.

Are there benefits of taking part in the study?
There may be no direct benefit to you, but joining this study will provide useful information that will help to improve HIV health and water insecurity programs for communities in this region including yours, and elsewhere. We will however compensate you for your time and actual transport costs should you incur them to participate in the study.

Will your identity be kept private and the information you give kept confidential?
We will not write your name in any of our reports. Your name will only be in this consent form. We will not link your name to your response in any way. We will give you a unique number which will be used in place of your name. The information you give us will be kept confidential. The information collected from you will not be shared with your family or anyone outside the research team. All information will be locked up in a cabinet for up to 5 years after the study is completed and electronically for up to 10 years. The recorded information will be erased from the audio-recorder after the information has been written down and verified. Only staff with permission will see your records but will not be able to know your identity.

Do you have to take part in this study?
No, you do not have to. Your participation in the study is voluntary and by choice. You are free to withdraw your participation or decline to answer any question you are not comfortable with. Choosing not to take part or answer any question will not lead to any penalty or loss to you. Your decisions will not prevent you from receiving any routine services that you already get. Everybody aged 15-64 who is enrolled in ART care at your facility has an equal chance of participating in this study. No one will be unfairly disadvantaged with regards to selection for participation.

Whom to call if you have questions, concerns or think you have been harmed in this study
Should you have any questions, concerns, or complaints about the study, or if you think you have been harmed (injured) by the study, please contact Jacquelyne Odak through this address and telephone number: P.O. Box 3505, Kisumu 40100. Tel. **0722 390608**. She is based in Kisumu at Maseno University's Varsity Plaza, Kisumu town.

Who should you call if you have questions about your rights as a study participant?
If you have questions about your rights as a person in the study, you may contact Dr Bonuke Anyona of Maseno University Scientific and Ethics Review Committee on **0721 543976.**

Feel free now to ask me any question or clarification about everything I have shared with you.

Participant Statement:

The study has been explained to me. I have had a chance to ask questions. These have been answered to my satisfaction. I voluntarily agree to participate in the study by signing below. I understand that I can withdraw from the study at any time.

For participants aged 15 – 17 years

Assent to participate given? **Yes** ☐ **No** ☐

Respondent's Sign _____ **OR Thumb Print:** _____

Date: _____

For parents/guardians:

The person being considered for this study is legally unable to consent for herself/himself because s/he is a child. By signing this form, you are giving permission for your child or ward to participate in the study

Informed consent obtained? **Yes** ☐ **No** ☐

Parent/Guardian's Sign _____ **OR Thumb Print:** _____

Date: _____

For participants aged 18 – 64 years

Informed consent obtained? **Yes** ☐ **No** ☐

Respondent's Sign _____ **OR Thumb Print:** _____

Date: _____

☐Participant Copy ☐Researcher Copy

Principal Investigator and Institutional affiliation: Jacquelyne Odak, Maseno University - Box 3505 Kisumu 40100. Tel. **0722-390608**

Study Coordinator and contact info: Weldon Kwach, Maji Matamu Water Purification. P.O. Box 46000, Nairobi. Tel. **0715-505565**

III. STUDY TOOLS

HOUSEHOLD QUESTIONNAIRE

Onsite survey on water insecurity
*Administer the written informed consent form and obtain consent before proceeding
*Please select the response by marking ☒ on the choices
*Informed consent obtained? ☐YES ☐ NO
If NO, thank the respondent and excuse yourself without asking any other question.

SOCIO- ECONOMIC & DEMOGRAPHICS

	PARTICIPANT UNIQUE ID ☐☐☐☐☐☐ (alphanumeric digits) PARTICIPANTDOB (DD/MM/YEAR) PARTICIPANT SEX ☐ TOTAL NUMBER IN HOUSEHOLD ☐☐			DATE OF INTERVIEW (DD/MM/YEAR) **GPS READING: (autocapture)	
LEVEL OF EDUCATION	**MARITAL STATUS**	**EMPLOYMENT STATUS**	**MAJOR ASSETS**	**TYPE OF HOUSING**	**AV. MONTHLY INCOME**
☐None	☐ Never married	☐Unemployed	☐Farmland	☐Temporary	☐< 5000/month
☐Some Primary	☐Currently married	☐Self-employed	☐Livestock	☐Semi-permanent	☐< 10000/month
☐Primary complete	☐ Separated	☐Casual laborer	☐House	☐Permanent	☐< 20000/month
☐Secondary incomplete	☐ Divorced	☐Temporary	☐Tricycle /Tuktuk	☐Shack	☐< 30000/month
☐Secondary complete	☐ Widowed	☐Employed - salary	☐Motorbike		☐> 30000/month
☐College education	☐ Cohabiting		☐Bicycle		

WATER INSECURITY

Q1. What kind of water problem do you experience?

No water for domestic use	☐YES	☐NO
No water for farming	☐YES	☐NO
Too much water/ flooding /water-logged soils	☐YES	☐NO
Low water table	☐YES	☐NO
High water table	☐YES	☐NO
No water supply/connectivity	☐YES	☐NO
Polluted water	☐YES	☐NO
Other (specify)		

Q2. Is the water problem permanent? ☐ YES ☐NO

Q3. What is the reason you are having problems with water?

Lack of rains	☐YES	☐NO
Few/no natural water sources	☐YES	☐NO
Flooding	☐YES	☐NO
Geographic location	☐YES	☐NO
Effects of climate change	☐YES	☐NO
Poor infrastructure	☐YES	☐NO
Polluted water	☐YES	☐NO
Costs are high	☐YES	☐NO
Conflict	☐YES	☐NO
Other (specify)		

IMPACT ON HEALTH

Q4. Has the water problem caused you any health problems? ☐ YES ☐NO

If NO, skip to Q 6

Q5. What do you do to ensure your water is safe?

Treating with chemical like water guard	☐YES	☐NO
Boiling	☐YES	☐NO
Filtering	☐YES	☐NO
Nothing	☐YES	☐NO

Q6. In the last 3 months, what health problems have you experienced as a result of the water insecurity?

Malaria	☐YES	☐NO
Diarrhea	☐YES	☐NO
Worms	☐YES	☐NO
Other (specify)		

Q7. Apart from these health problems, do you worry about the water problem? ☐ YES ☐ NO

Q8. In the past 6 months, did you experience any food-related problems as a result of water insecurity? ☐YES ☐ NO

If NO, skip to Q11

Q9. What food related problems did you experience?

Food not available	☐YES	☐NO
Can't buy food with ease	☐YES	☐NO
Can't produce enough food	☐YES	☐NO
Food gets destroyed	☐YES	☐NO
Other (specify)		

Q10. What did you do to cope with the food problem?

Ask for assistance	☐YES	☐NO
Fewer meals per day	☐YES	☐NO
Smaller portions per meal	☐YES	☐NO
Other (specify)		

Q11. Nutritional status

Weight in Kgs:_____ Height in cm:_____ BMI auto fill:_____

Q12. In the past 6 months, did you experience any challenges with obtaining your ART medication? ☐YES ☐ NO

If NO, skip to Q14

Q13. What challenges in accessing ART have you experienced as a result of the water problem?

Poor road access	☐YES	☐NO
Health facilities closed	☐YES	☐NO
Displacement from settlement	☐YES	☐NO
Other (specify)		

Q14. In the last 3 months, was there a 4-day continuous period when you missed your ART medication due to water problems? ☐ YES ☐NO

LIVELIHOODS

Q15. In the past 6 months, were your means of earning a living affected by water problems?

☐YES ☐ NO

If NO, skip to 16

Q16. In what ways have your income generating activities been affected by the water problem?

Loss of crops	☐YES	☐NO
Loss of livestock	☐YES	☐NO
Loss of other assets	☐YES	☐NO
Reduced earnings	☐YES	☐NO
Loss of livelihood	☐YES	☐NO
Other (specify)		

SETTLEMENT

Q17. In the past 6 months, has the water problem interfered with your housing?

☐YES ☐ NO

If NO, thank the respondent and end the interview.

Q18. Which housing or settlement problems have you experienced in the last 6 months as a result of water problems?

Damaged housing	☐YES	☐NO
Loss of property	☐YES	☐NO
Loss of farmland	☐YES	☐NO
Displacement	☐YES	☐NO
Exposure to harsh elements	☐YES	☐NO
Exposure to wildlife (snakes, hippos, etc)	☐YES	☐NO
Other (specify)		

Collect copy of the signed Informed Consent Form, thank the respondent and end the interview.

****Prompt for research assistant to:**

1. Take the GPS readings if not yet done.
2. Take height and weight measurements if not yet done.
3. Save data

Saved data will not synchronize without these records.

HOUSEHOLD WATER INSECURITY EXPERIENCES SCALE (HWISE)

I will now ask you about your household's experiences with water. By household, I mean a house in which members sleep and share food from the same pot. For each experience, we want to know in how many months this happened to you during the last one month. Even if it happened just once during a month, we would like you to count that month.

#	HWISE ITEMS		0 Never	1 Rarely	2 Sometimes	3 Often/ Always
1	Worry	In the last 4 weeks, how frequently did you or anyone in your household worry you would not have enough water for all of your household needs?				
2	Interrupt	In the last 4 weeks, how frequently has your main water source been interrupted or limited (e.g. water pressure, less water than expected, river dried up)?				
3	Clothes	In the last 4 weeks, how frequently have problems with water meant that clothes could not be washed?				
4	Plans	In the last 4 weeks, how frequently have you or anyone in your household had to change schedules or plans due to problems with your water situation? (Activities that may have been interrupted include caring for others, doing household chores, agricultural work, income-generating activities, sleeping, etc.)				
5	Food	In the last 4 weeks, how frequently have you or anyone in your household had to change what was being eaten because there were problems with water (e.g., for washing foods, cooking, etc.)?				
6	Hands	In the last 4 weeks, how frequently have you or anyone in your household had to go without washing hands after dirty activities (e.g., defecating or changing diapers, cleaning animal dung) because of problems with water?				
7	Body	In the last 4 weeks, how frequently have you or anyone in your household had to go without washing their body because of problems with water (e.g., not enough water, dirty, unsafe)?				

8	Drink	In the last 4 weeks, how frequently has there not been as much water to drink as you would like for you or anyone in your household?				
9	Angry	In the last 4 weeks, how frequently did you or anyone in your household feel angry about your water situation?				
10	Sleep	In the last 4 weeks, how frequently have you or anyone in your household gone to sleep thirsty because there wasn't any water to drink?				
11	None	In the last 4 weeks, how frequently has there been no useable or drinkable water whatsoever in your household?				
12	Shame	In the last 4 weeks, how frequently have problems with water caused you or anyone in your household to feel ashamed/excluded/stigmatized?				

Scoring

Each of the 12 items are scored 0 (never), 1 (rarely), 2 (sometimes), or 3 (often/always), for a total score range of 0-36. A score of 12 or more is considered water insecure for the HWISE and IWISE scales.

INDIVIDUAL WATER INSECURITY EXPERIENCES SCALE (IWISE)

I will now ask you about your household's experiences with water. For each experience, we want to know in how many months this happened to you during the **last 12 months**. Even if it happened just once during a month, we'd like you to count that month.

#	IWISE ITEMS		**0 Never**	**1 Rarely**	**2 Sometimes**	**3 Often / Always**
1	Worry	In the last 12 months, how often did you worry that you would not have enough water for all your needs?				
2	Interrupt	Please think about where you get most of your water, such as tap, well, borehole, river, lake, etc. How often was this water source interrupted or limited in any way during the last 12 months?				
3	Clothes	In the last 12 months, how often could your clothes not be washed because of problems with water?				

4	Plans	In the last 12 months, how often did you have to change schedules or plans because of problems with water? (Activities that may have been interrupted include caring for others, doing household chores, agricultural work, income-generating activities, sleeping, etc.)				
5	Food	Still thinking about the last 12 months, how often did you change what you ate because of problems with water?				
6	Hands	In the last 12 months, how often were you not able to wash your hands after dirty activities because of problems with water?				
7	Body	In the last 12 months, how often were you not able to wash your body because of problems with water?				
8	Drink	In the last 12 months, how often did you not have as much water to drink as you would have liked?				
9	Angry	Still thinking about the last 12 months, how often did you feel angry because of problems you were experiencing with water?				
10	Sleep	In the last 12 months, how often did you go to sleep thirsty because there was no water to drink?				
11	None	In the last 12 months, how often did you have no usable or drinkable water whatsoever?				
12	Shame	In the last 12 months, how often did you feel shame because of problems you were experiencing with water during the last 12 months?				

Scoring

Each of the 12 items are scored 0 (never), 1 (rarely), 2 (sometimes), or 3 (often/always), for a total score range of 0-36. A score of 12 or more is considered water insecure for the HWISE and IWISE scales.

HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS)

SCREENING FOR HIV OUTCOMES

1. **VLSUPP**
   What was your most recent viral load test result? ☐ Less than 200 copies/ml ☐ 200 copies/ml or more ☐ I do not know
2. **CD4**
   What was your most recent CD4 count? ☐ Less than 250 cells ☐ 250–499 cells ☐ More than 500 ☐ I do not know
3. **MISS_VST**
   In the past 12 months, how many times did you miss your scheduled clinic appointments?
   ☐ None ☐ 1–2 times ☐ 3–4 times ☐ 5 or more times
4. **OPP_INFXN (Check all that apply)**
   In the past 12 months, have you experienced any of the following opportunistic infections?
   ☐ TB ☐ Candidiasis ☐ Pneumocystis pneumonia (PCP) ☐ Other (specify: __ _) ☐ None
5. **TX_OPPINFXN**
   In the past 12 months, have you been diagnosed or treated for any opportunistic infections? ☐ Yes ☐ No

1	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to Q2) 1=Yes	
1A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
2	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (skip to Q3) 1=Yes	
2A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
3	In the past four weeks, did you or any household member have to eat a limited variety of foods (less kinds of food on the plate) due to a lack of resources?	0 = No (skip to Q4) 1=Yes	
3A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	

4	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip to Q5) 1=Yes	
4A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
5	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to Q6) 1=Yes	
5A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks 3 = Often (more than ten times in the past four weeks)	
6	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q7) 1=Yes	
6A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks 3 = Often (more than ten times in the past four weeks)	
7	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	0 = No (skip to Q8) 1=Yes	
7A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks 3 = Often (more than ten times in the past four weeks)	

8	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip to Q9) 1=Yes	
8A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks 3 = Often (more than ten times in the past four weeks)	
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (questionnaire is finished) 1=Yes	
9A	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks 3 = Often (more than ten times in the past four weeks)	

GENERALIZED ANXIETY TOOL

GAD-7 Anxiety

Over the last two weeks, how often have you been bothered by the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Feeling nervous, anxious, or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it is hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid, as if something awful might happen	0	1	2	3

Column totals _____ + _____ + _____ + _____ =

Total score _____

If you checked any problems, how difficult have they made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
☐	☐	☐	☐

Source: Primary Care Evaluation of Mental Disorders Patient Health Questionnaire (PRIME-MD-PHQ). The PHQ was developed by Drs. Robert L. Spitzer, Janet B.W. Williams, Kurt Kroenke, and colleagues. For research information, contact Dr. Spitzer at ris8@columbia.edu. PRIME-MD® is a trademark of Pfizer Inc. Copyright© 1999 Pfizer Inc. All rights reserved. Reproduced with permission

DEPRESSION TOOL

Patient Health Questionnaire-9 (PHQ-9)

	Over the last 2 weeks, how often have you been bothered by any of the following problems?	**Not at all**	**Several days**	**More than half the days**	**Nearly every day**
1	Little interest or pleasure in doing things	0	1	2	3
2	Feeling down, depressed, or hopeless	0	1	2	3
3	Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4	Feeling tired or having little energy	0	1	2	3
5	Poor appetite or overeating	0	1	2	3
6	Feeling bad about yourself – or that you are a failure or have let yourself or your family down	0	1	2	3
7	Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8	Moving or speaking so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9	Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3
PHQ-9 score is obtained by summing the score for each question (total points		0 +	___ +	___ +	___
		= Total score:_____			
Interpretation: Total scores of 0-4, 5, 10, 15, and 20 represent cut points for none/minimal, mild, moderate, moderately severe, and severe depression respectively.					

NB: Question 9 is a single screening question on suicide risk. A patient who answers YES to question 9 needs further assessment for suicide risk by an individual who is competent to assess this risk.

IDI GUIDE

Date :

☐☐/☐☐☐/☐☐☐☐

Day Month Year

Alpha-numeric Participant ID:

☐☐☐☐☐

FGD Number:

☐☐☐☐

Interviewer Initials:

☐☐

Thank you for taking the time to meet and speak with me today. My name is ……. from Maseno University. We are conducting research on water insecurity among persons living with HIV. By water insecurity, we mean problems related to water shortage, flooding, affordability, storage, and lack of safe water for household use. We are interested to better understand how water insecurity has affected you, and to hear about your lived experiences in terms of challenges with obtaining enough water, settlement, livelihood activities, conflict, and health. I will ask you some questions about your personal experiences with water insecurity and how it has affected your health and well-being. When answering the questions, please feel free to talk about any opinions or feelings you have on the subject. There are no right or wrong answers. Everything you will say is important. Since we don't want to miss anything, we discuss, we will record and take notes of our discussion. This discussion will take about one hour.

I will now give you details about the research, and if you are comfortable to participate, we will continue. Please feel free to ask any questions you may have.

(Informed consent administration. Mark your copy and give participant theirs.)

Perceived type and causes of water insecurity

1. I would like to hear your experiences with water insecurity – lack of it or excess of it. What has been your personal experience with problems related to water?
   (Probe for: Sources of water, Access (distance), Turn-around time, Daily consumption, Quantity per trip, Storage, Treatment if any)
2. Would you describe to me how long has this been a problem and how it started?
3. What would you say is the cause of the problem you mentioned?

(probe for location, climate, income levels, poor infrastructure, government policy)

Socio-economic Experiences

4. What would say are your main barriers to adequate water harvesting/sourcing and storage? (probes: distance, costs, storage facilities, availability, time)
5. What aspects of your social life have been most affected by water insecurity in terms of water requirements (Probes: domestic use and farming, food availability, settlement, livelihood activities, income, movement, family relations, education)
6. Please share with me an account of any incidence of conflict involving you that arose due to water insecurity, either within your household or at the water source.
7. Would you share with me some of the things you did to cope with the challenges you mentioned?

Health

8. There have been reports of people experiencing injuries due to water insecurity. Would you share with me any such experience you have had especially when trying to obtain water?
9. Many people with limited access to water are usually not at peace. In what ways has water insecurity affected your mental wellbeing? (Probe for stress, anxiety, worry)
10. Can you share with me about any water-related health problems that have been experienced by you and other members of you household? (Probe for malaria, diarrheal diseases, intestinal worms, typhoid, bilharzia, other)
11. Now, I would like us to talk about your health concerning ART. In what ways has your experience of water insecurity affected your ART adherence? (Probe for inaccessibility, displacement, forgetfulness, lack of transport, lack of food, alternative medication, health facility closed, other)
12. In the last 3 months, how many times were you unable to take your medication as required?
13. In the same period, how many times were you unable to take medication for 4 continuous days?
14. Tell me about any unpleasant reactions you experienced due to your medication in the last 6 months and if it prevented you from taking your medication.
15. What did you do to address the health problem?

16. Now I would like to give you an opportunity to talk about anything else that we may have left out of our discussion.

That brings me to the end of the questions I had. I would like to ask if you have any questions for me.

Thank you so much for your time and for sharing this important information. It shall be kept confidential and used only for research purposes. Call the number on the consent form you have remained with in case of any concerns.

FGD GUIDE

Date : ☐☐/☐☐☐/☐☐☐☐ Day Month Year	FGD Number: ☐☐☐☐ Interviewer Initials: ☐☐

Thank you for taking the time to meet and speak with me today. My name is …… from Maseno University. We are conducting research on water insecurity among persons living with HIV. By water insecurity, we mean problems related to water shortage, flooding, and lack of safe water. We are interested to better understand how water insecurity has affected your community, and to hear about your shared experiences in terms of water availability, affordability, reliability, safety, settlement, livelihood activities, conflict, and health. We will ask you some questions about your experiences with water insecurity and how it has affected your health and well-being. When answering questions, please feel free to talk about any opinions or feelings you have on the subject.

In this discussion, we will not use our names at all. Instead, everyone will get a number to use for identity. Before you respond to any question, please say **"as number X, my experience concerning that has been…")** then give your opinion. If you want to refer to another participant, refer to them using the number card in front of them, for example, **"just as number X has said…".**

There are no right or wrong answers. Everyone's opinion is important. Let us give each other a chance to express ourselves and avoid interrupting even though we don't agree with what someone has said. Since we don't want to miss anything that we discuss, we will record our discussion and

take some notes. This discussion will take about one and a half hours. We will now give you details about the research, and if you are comfortable to participate, we will continue. Please feel free to ask any questions you may have.

(Informed consent administration. Mark your copy and give participant theirs)

Issue number cards to represent each participant in lieu of their names

A. Perceived type and causes of water insecurity

1. What would you say is the main water problem in this community?
   (Probe for: availability, access (distance), water quality, affordability, reliability).
2. Would you describe to me how long this has been a problem and how it started?
3. What would you say are the main causes of the water problem in this community?
   (probe for location, climate, ground water coverage, distance to water sources, income levels, poor infrastructure, government policy, pollution, hazards)
4. What is the main source of water for domestic use in this community? What about for farming?

B. Socio-economic Experiences

5. What **aspects of your lives have been most affected** by water insecurity in terms of water requirements (Probes: domestic use, farming, business, daily routines)
6. In recent years, this area has experienced a lot of flooding/drought. Can you recount to me **how the flood waters/drought affected you**?
   (Probe for: Farming activities (crops and livestock), settlement and housing, , assets, movement).
7. What would you say are **your main barriers to adequate water harvesting/sourcing and storage**? (probes: distance, costs, storage facilities, availability, time, insecurity, conflict)
8. In what ways has water insecurity affected your **livelihood/income generating activities**?
9. Please share with me an account of any incidences of conflict that arose due to water insecurity in the community.
10. Who, between men, women and children would you say are most affected by water insecurity, and why?

11. One of the problems that results from water insecurity is reduced **food availability**. In what ways has water insecurity affected your food sources as a community?
12. Would you share with me some of the things you do to **cope with the challenges** of water insecurity?
13. How has the community responded to the water insecurity, could you talk about any collective efforts to solve the water insecurity problem?
14. (**Men only**): In your culture, whose responsibility is it to ensure there is water for domestic use? What do you do when there is insufficient water at home?
15. (**Women only**): What can you say regarding the experience of domestic or **gender-based violence** as a result of water insecurity?

C. Health

16. There have been reports of people **experiencing injuries** due to water insecurity. Would you share with me any such experience especially when trying to obtain water?
17. In what ways has water insecurity affected your **physical health?** (Probes: Adhering to treatment, water-related illnesses)
18. Please share with me the ways in which water insecurity has affected your **emotional and psychological well-being/mental health?** (probes: stress, anxiety, depression)
19. I would now like to ask if you have any other water related concerns to share that we have not talked about.

That brings me to the end of the questions I had. If any of you has a question for me, please feel free to ask.

Thank you so much for your time and for sharing this important information. It shall be kept confidential and used only for research purposes. Call the number on the consent form you have remained with in case of any concerns about this discussion.

IV Maseno University School of Graduate Studies (SGS) Proposal Approval

MASENO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Office of the Dean

Our Ref: PHD/PH/000058/2018

Private Bag, MASENO, KENYA
Tel:(057)351 22/351008/351011
FAX: 254-057-351153/351221
Email: sgs@maseno.ac.ke

Date: 23rd January, 2024

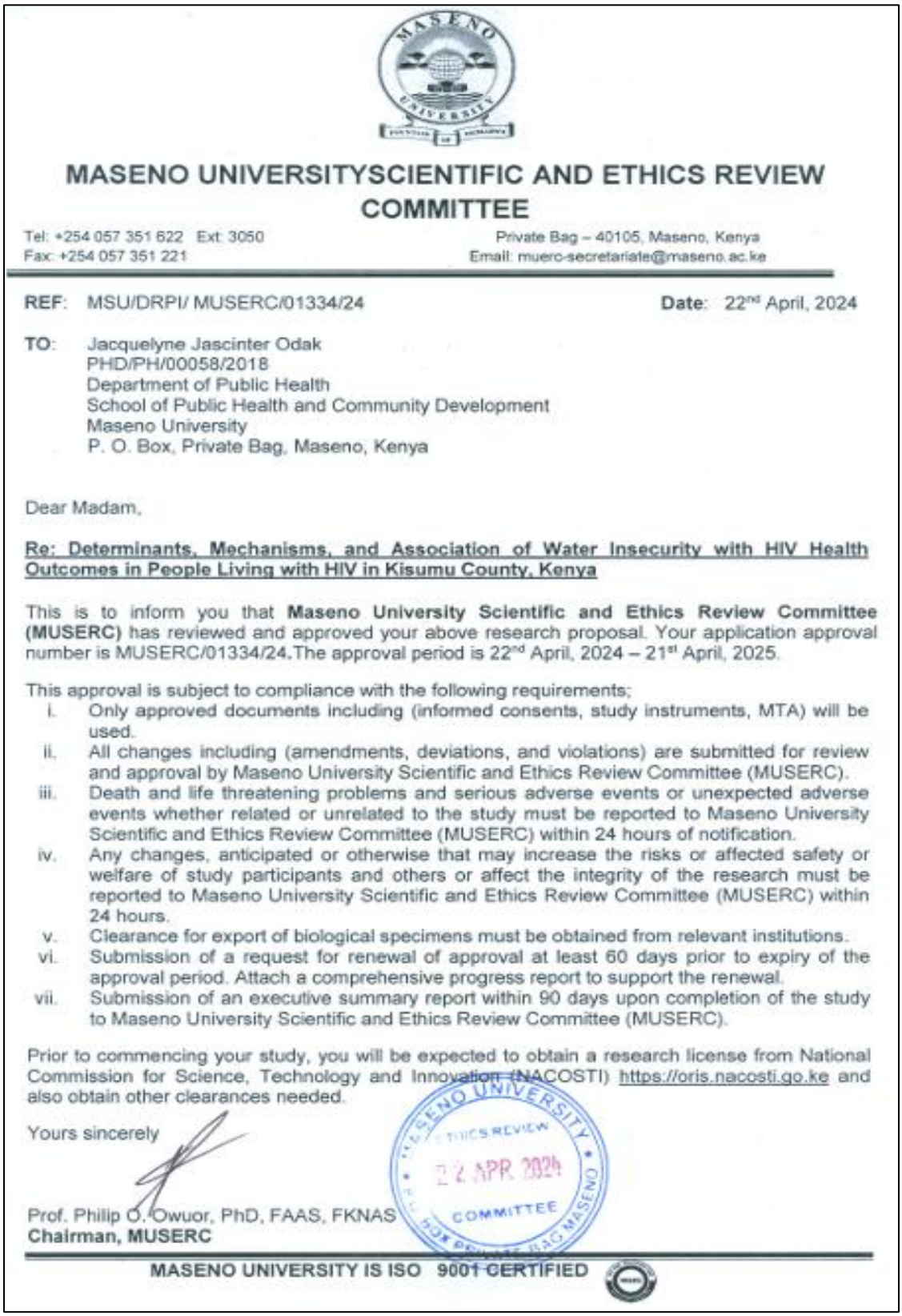
TO WHOM IT MAY CONCERN

RE: PROPOSAL APPROVAL FOR JACQUELYNE JASCINTER ODAK — PHD/PH/00058/2018

The above named is registered in the programme of Doctor of Philosophy in Public Health in the School of Public Health and Community Development, Maseno University. This is to confirm that her research proposal titled **"Determinants,Mechanisms and Association of Water Insecurity with HIV Health Outcomes in People with HIV in Kisumu County,Kenya"** has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

Prof. J.O. Agure
DEAN, SCHOOL OF GRADUATE STUDIES

V MUSERC Approvals (original and extension)



MASENO UNIVERSITYSCIENTIFIC AND ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

REF: MSU/DRPI/ MUSERC/01334/24 **Date**: 22nd April, 2024

TO: Jacquelyne Jascinter Odak
PHD/PH/00058/2018
Department of Public Health
School of Public Health and Community Development
Maseno University
P. O. Box, Private Bag, Maseno, Kenya

Dear Madam,

Re: Determinants, Mechanisms, and Association of Water Insecurity with HIV Health Outcomes in People Living with HIV in Kisumu County, Kenya

This is to inform you that **Maseno University Scientific and Ethics Review Committee (MUSERC)** has reviewed and approved your above research proposal. Your application approval number is MUSERC/01334/24.The approval period is 22nd April, 2024 – 21st April, 2025.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by Maseno University Scientific and Ethics Review Committee (MUSERC).
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to Maseno University Scientific and Ethics Review Committee (MUSERC).

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely

Prof. Philip O. Owuor, PhD, FAAS, FKNAS
Chairman, MUSERC

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE 24 APR 2024 P.O. BOX PRIVATE BAG MASENO

MASENO UNIVERSITY IS ISO 9001 CERTIFIED

MASENO UNIVERSITYSCIENTIFIC AND ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221
Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

REF: MSU/DRPI/ MUSERC/01334/24 **Date**: 9th December, 2025

TO: Jacquelyne Jascinter Odak
PHD/PH/00058/2018
Department of Public Health
School of Public Health and Community Development
Maseno University
P. O. Box, Private Bag, Maseno, Kenya

Dear Madam,

Re: Determinants, Mechanisms, and Association of Water Insecurity with HIV Health Outcomes in People Living with HIV in Kisumu County, Kenya

This is to inform you that **Maseno University Scientific and Ethics Review Committee (MUSERC)** has reviewed and approved your above application for study **continuation**. Your application approval number is MUSERC/01334/24.The approval period is 9th December, 2025 – 8th December, 2026.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by Maseno University Scientific and Ethics Review Committee (MUSERC).
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to Maseno University Scientific and Ethics Review Committee (MUSERC).

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely

Dr. Bonuke Anyona, PhD
Chairman, MUSERC

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE 09 DEC 2025 P.O. BOX PRIVATE BAG MASENO

VI NACOSTI License

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **665943**

Date of Issue: **18/June/2024**

RESEARCH LICENSE



This is to Certify that Ms.. JACQUELYNE JASCINTER ODAK of Maseno University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kisumu on the topic: DETERMINANTS, MECHANISMS, AND ASSOCIATION OF WATER INSECURITY WITH HIV HEALTH OUTCOMES IN PEOPLE LIVING WITH HIV IN KISUMU COUNTY, KENYA for the period ending : 18/June/2025.

License No: **NACOSTI/P/24/36726**

665943

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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

See overleaf for conditions

VII Kisumu County Department of Medical Services, Public Health & Sanitation Approval

REPUBLIC OF KENYA

COUNTY GOVERNMENT OF KISUMU

Telegrams: "PRO (MED)"
Tel: 254-057-2020105
Fax: 254-057-2023176
E-mail: kisumucdh@gmail.com

Director of Public Health, Preventive/
Promotion and Environmental Health
P.O. Box 721 – 40100
Kisumu.

DEPARTMENT OF MEDICAL SERVICES, PUBLIC HEALTH & SANITATION

Our Ref: GN 133 VOL. XVII/(032) **Date:** 24th June 2024

All SCMOHs

RE: APPROVAL TO CONDUCT RESEARCH IN KISUMU COUNTY

The Department has reviewed and approved this research titled: ***'Determinants, Mechanisms and Association of Water Insecurity with HIV Health Outcomes in people living with HIV in Kisumu County'.***

The purpose of this letter is to request you to allow **Ms. Jacqueline Jacinter Odak** who is the **Principal Investigator** and the **County Co-Principle Investigator, Director Fredrick O. Oluoch** to conduct the research.

Thank you for your continued support.

COUNTY DIRECTOR
2 JUN 2024
DEPT. OF MEDICAL SERVICES & SANITATION
P. O. Box 721 - 40100,
KISUMU.

Fredrick O. Oluoch, MPH, MBA, HSC, OGW
Director - Public Health & Sanitation
Kisumu County

VIII: Physicochemical Parameters tested on 34 water samples (n=23) with WHO acceptable ranges

	Sample	pH	Conductivity	TDS	TSS	Cl	NH_4NO_3	Cd	NO_3	Zn	Ca	Mg	K	SO_4	Fe	Mn	Na	HCO_3	PO_4	Al	B	Cu	Pb	Turbidity
	WHO Range	6.5-8.5	800 Max	2000 Max	250 Max	250 Max	3.0 Max	0.5 Max	10 Max	5 Max	150 Max	100 Max	50 Max	400 Max	0.3 Max	0.1 Max	200 Max	150 Max	30Max	0.2 Max	1.0 Max	1.0 Max	0.01 Max	5 Max
1	Borehole Seme Mama Leah	7.02	454	227	ND	14.18	1.68	0.001	6.16	0.02	57.8	20.1	4.51	21.8	0.12	ND	48.5	362.95	2.15	0.03	0.01	0.02	0.01	1.44
2	Borehole Seme Wang Agot	7.29	718	359	ND	29.07	1.68	0.001	2.24	0.01	85.8	28.4	7.02	14.59	0.1	ND	80.1	610	2.15	ND	ND	0.01	0.01	0.28
3	Well Seme No Khoseah	7.12	861	408	ND	25.17	1.68	0.001	9.52	0.01	124	40.7	9.76	119.5	0.11	0.13	67.3	628.3	2.15	ND	0.02	0.01	0.01	0.27
4	Seme River Nyamgum	8.08	359	179	ND	30.13	2.8	0.001	1.68	0.01	20.3	4.29	3.76	12.04	1.9	0.03	27.2	161.65	2.18	3.05	0.03	0.02	0.01	55
5	Seme River Ochuri	8.61	598	299	ND	5.67	3.92	0.001	3.92	0.01	22.9	5.86	3.03	11.71	1.37	ND	35	198.25	2.24	1.74	ND	0.02	0.01	25.38
6	Ahe River Nyando-1	8.66	885	442	ND	4.96	2.8	0.001	1.68	0.01	33.8	11.1	11.4	13.09	0.34	ND	35	262.3	2.36	0.28	ND	0.02	0.01	15.72
7	Pond AHR Junction	9.12	430	215	ND	3.9	1.68	0.001	2.8	0.01	12.9	1.92	10.3	8.81	0.22	ND	20.6	146.4	2.18	0.17	0.04	0.02	0.01	31.52
8	Borehole AHR Kol Sch	8.58	2,394	1,197	ND	48.21	1.68	0.002	6.16	0.01	33	2.39	48.5	126.99	0.09	ND	153	76.25	2.15	2.6	0.03	0.003	0.01	0.58
9	Nyak River Awach 1	8.04	167	83	ND	3.19	4.48	0.001	3.36	0.01	3.26	0.6	5.34	2.7	1.69	ND	153	76.25	2.15	2.6	0.03	0.02	0.01	22.02
10	Nyak Apida Pond	7.6	167	83	ND	2.48	4.48	0.002	2.8	0.03	3.9	1.52	7.21	2.43	10.4	0.06	12.5	73.2	2.45	11.9	ND	0.02	0.01	71
11	Nyak River Asao	8.65	670	335	ND	6.03	2.8	0.001	3.92	0.01	18.5	3.13	7.42	12.28	0.5	ND	47.1	207.4	2.15	0.47	0.03	0.02	0.004	121
12	Nyak Tap Scouts Jamii Project	7.15	263	131	ND	2.13	2.24	0.001	2.04	0.01	2.97	0.52	3.18	69.48	0.07	ND	22.7	27.45	2.15	0.01	0.02	0.03	0.01	2.08
13	Nyak Checkpoint Pond	8.56	646	323	ND	10.64	3.36	0.002	1.68	0.04	14.1	3.77	15.5	13.44	12	0.33	46.2	82.35	2.54	20.6	ND	0.04	ND	198
14	BH St. Annes Ahero	7.38	2,681	1,340	ND	24.11	1.68	0.001	11.76	0.04	66.3	5.53	34.6	84.16	0.1	ND	161	397.8	2.18	ND	0.04	0.01	ND	0.25
15	Lake Victoria Ahero 1	7.31	2,370	1,185	ND	19.85	2.8	0.0004	11.76	0.01	72.7	6.02	29.3	25.7	0.1	ND	155	649.65	2.15	ND	0.04	0.001	ND	0.28
16	Lake Victoria Nyakach 1	7.41	837	418	ND	2.83	2.24	0.002	3.92	0.01	36.8	10.8	3.98	16.08	0.31	0.12	45.4	347.7	2.15	0.13	0.004	0.02	0.01	19.38
17	Lake Victoria Ogenya Ahero	7.06	35	18	ND	40.47	1.12	0.23	2.24	0.1	12.1	9.49	1.21	13.06	47.6	0.23	5.62	259.25	1.84	33.3	0.002	0.23	ND	449
18	Lake VictoriaNyakach 2	8.62	78	39	ND	50.06	2.28	0.02	1.12	0.23	23.9	1.45	4.62	261.43	0.12	0.15	7.95	152.5	0.52	8.82	0.001	0.02	ND	173
19	Lake Victoria Seme1	7.3	39	19	ND	8.88	1.68	ND	3.36	2.44	2.56	1.45	4.62	261.43	0.12	0.04	10.3	106.75	0.18	0.14	0.003	0.01	ND	8.08
20	Lake Victoria Seme 2	7.51	39	19	ND	5.33	1.68	ND	2.24	0.002	2.77	1.55	4.63	10.6	0.12	0.02	10	118.95	0.18	0.03	0.002	0.01	0.002	6.89
21	River Nyando 2	7.95	54	27	ND	12.43	2.8	ND	6.16	0.02	8.35	4.26	7.27	11.68	11.6	0.1	12.1	88.5	0.1	13.7	0.01	0.02	ND	210
22	River Nyando 3	8.1	59	29	ND	11.36	1.63	ND	3.36	0.03	7.13	3.86	7.09	13.12	12.1	0.08	12.9	125.05	0.86	14.1	0.01	0.02	0.002	228
23	River AWACH 2	7.61	39	19	ND	13.14	4.48	ND	3.36	0.01	3.78	2.63	1.97	11.41	4.06	0.22	9.31	100.65	0.34	4.35	0.003	0.01	ND	82
24	Kombeya Soko	6.39	34	12	ND	13.14	3.92	ND	2.24	0.02	0.54	0.23	2.94	11.74	5.35	0.08	9.05	36.6	0.61	6.37	0.004	0.01	ND	302
25	Ahero Irrigation Inlet	8.57	166	83	ND	10.65	1.12	0.02	1.12	0.04	42.8	15.1	11.4	40.73	1.04	1	11.4	610	0.92	3.15	0.02	0.1	ND	75
26	Protected Well, Ahero	8.73	239	120	ND	10.3	1.12	0.004	2.24	0.001	43.2	11	50.6	40.73	0.01	0.16	13.3	811.3	0.31	ND	0.02	0.03	ND	2.45
27	Shallow Unprotected well Ahero	7.53	44	22	ND	21.5	1.12	0.003	1.12	0.01	12.3	4.82	7.22	8	3.74	0.54	4.35	198.25	0.12	4.51	0.02	0.04	ND	179
28	Rain Tank Water Ahero	8.7	344	172	ND	67.45	1.68	0.003	33.6	0.002	5.18	11.7	95.7	286	0.1	0.01	33.6	796.05	0.31	ND	0.03	0.03	ND	5.55
29	Asao Shallow Well Nyakach	8.73	172	86	ND	13.14	1.68	0.004	1.68	ND	37.3	3.14	50.2	51.21	0.2	0.1	22.9	713.7	0.35	0.04	0.02	0.03	ND	31.94
30	Asao Rain Tank Water Nyakach	5.01	6	3	ND	4.97	2.24	0.001	1.68	0.13	1.25	0.66	1.47	7.31	0.02	0.02	2.74	33.55	0.12	0.03	0.01	0.04	ND	1.5
31	Protected Well Nyakach County Hospital	8.8	264	123	ND	22.72	1.68	0.003	3.92	0.01	24.5	6.32	29	55.11	0.01	0.01	35.2	924.15	0.43	ND	0.02	0.02	ND	0.61
32	Rain Tank Water Kadianga Nyakach	6.5	6	3	ND	4.26	2.8	0.0001	1.68	0.01	0.77	0.46	1.89	7.01	0.11	0.01	2.7	33.55	0.12	0.03	0.01	0.03	ND	3.26
33	Stream-Soko Nyakach	8.21	31	16	ND	14.56	22.7	0.002	2.24	0.01	13	5.88	9.06	22.7	1.17	0.04	5.81	195.2	0.31	2.08	0.02	0.03	ND	21.69
34	Stream- Bodi Nyakach	7.64	18	9	ND	28.4	2.24	0.01	2.24	0.1	4.19	2.84	8.05	6.83	14.8	0.08	5.24	131.15	0.25	40.7	0.03	0.04	ND	123

Exceedances are in red font. Green highlight shows the only two water samples with no physicochemical exceedances.

Data are available upon request.