

Implications of informal settlement characteristics for household water and sanitation services in Kakamega Municipality, Kenya

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ABSTRACT

Informal settlements are commonly characterized by concentrated populations, inadequate infrastructure and poor living conditions that may constrain household water, sanitation and hygiene (WASH) services. Anchored on Urban Political Ecology (UPE) theory, this study examined the implications of informal settlement characteristics for household WASH services in Kakamega Municipality, Kenya. A cross-sectional research design was used, targeting 1,202 households in five informal settlements, namely, Amalemba, Kambi Somali, Makaburini/Alkarim, Masingo and Juakali. The settlements were purposively selected, while 291 households were proportionately allocated and selected through simple random sampling. Key informants and focus group participants were purposively selected, with snowball sampling used to identify additional key informants. Data were collected using structured household questionnaires; key informant interviews (KIIs), focus group discussions (FGDs), field observations and document review. Quantitative data were analyzed using frequencies, percentages, the chi-square test of independence and Cramer's V. Qualitative data were analyzed thematically. The findings showed inadequate infrastructure, closely spaced housing and poor environmental conditions. Environmental pathways had the strongest associations with household WASH services, particularly solid-waste disposal ($\chi^2 = 196.45$, $df = 2$, $p < .001$, $V = .79$) and flooding/poor drainage ($\chi^2 = 188.08$, $df = 2$, $p < .001$, $V = .77$). Economic and social pathways were also significantly associated with WASH services. Accessibility, reliability and affordability were substantially constrained, with 72.5% of households requiring more than 30 minutes obtaining water, 95.2% experiencing service interruptions sometimes or often, and 64.6% reporting WASH services as unaffordable or very unaffordable. The study concludes that household WASH conditions are associated with interconnected settlement characteristics, and their environmental, economic and social pathways. The study recommended integrated settlement upgrading focused on water supply, sanitation, drainage, solid-waste management and physical access, alongside stronger community participation, affordable and reliable service provision, and settlement regularization.

Keywords: Household Water and Sanitation Services, Informal Settlement Characteristics, Kakamega Municipality

I. INTRODUCTION

Urbanization is transforming settlement patterns and increasing demand for basic urban services including water and sanitation. More than half of the world's population lives in urban areas, and urban populations are expected to continue increasing in the coming decades (United Nations, 2023). In many low- and middle-income countries, however, the expansion of housing, infrastructure and basic services has not kept pace with urban growth. Informal settlements have consequently become an important component of urban development, accommodating populations that may have limited access to planned housing and formal services. They are commonly characterized by high population concentration, inadequate infrastructure, insecure tenure, unplanned spatial layouts and poor living conditions (Ezeh et al., 2017; Lilford et al., 2017). These characteristics shape the physical and institutional conditions under which essential urban services are accessed.

The relationship is particularly important for water, sanitation and hygiene (WASH) services. High population concentration and closely spaced housing can increase pressure on existing facilities and constrain the extension, operation and maintenance of service infrastructure. Deficient water and sanitation infrastructure, poor drainage and inadequate waste management may further affect service reliability and usability, while environmental degradation can increase exposure to contamination and flooding (Bishoge, 2021; Douglas et al., 2008; Silvestri et al., 2018). At the household level, the implications extend beyond physical access because unreliable provision may require households to seek alternative sources, increasing the time and financial resources needed to obtain services. Household WASH

conditions are therefore shaped not only by the presence of infrastructure but also by the characteristics of the settlements in which households live.

In Kenya, these challenges occur alongside continuing urban development and informal settlement expansion. Studies have shown inadequate infrastructure, overcrowding, environmental risks and limited access to formal urban services in informal settlements, particularly in Nairobi and other urban areas (Joshi et al., 2023; Simiyu et al., 2019). Furthermore, researches have linked employment and household economic conditions with water affordability, while those of sanitation and settlement upgrading have highlighted the importance of social relations, community participation and equitable access to services (Joshi et al., 2022; Corburn & Sverdlik, 2017; Mitra et al., 2017). This indicates that household WASH challenges have multiple dimensions that cannot be adequately explained by infrastructure deficits alone.

The pathways through which settlement characteristics relate to household WASH services can be considered environmental, economic and social. Environmental pathways include inadequate waste management, poor drainage, flooding and contamination, which may disrupt water and sanitation services (Douglas et al., 2008; Lebu et al., 2024). Economic pathways include livelihood constraints, employment conditions and the financial burden of obtaining water and sanitation services, particularly where households depend on alternative providers (Joshi et al., 2022; Joshi et al., 2023). Social pathways include insecurity, community cooperation and perceived fairness in access to shared facilities, which may influence how services are accessed, used and managed (Corburn & Sverdlik, 2017; Mitra et al., 2017). These pathways provide a basis for linking observable settlement characteristics with household experiences of WASH accessibility, reliability and affordability.

This perspective is relevant to Kakamega Municipality, a secondary urban municipality in western Kenya where urban growth has occurred alongside informal settlement development. The study focused on Amalemba, Kambi Somali, Makaburini/Alkarim, Masingo and Juakali, where differences in population concentration, infrastructure conditions and living conditions provide a basis for examining variation in household WASH conditions. Although government and other stakeholders have undertaken measures to improve infrastructure and service provision, household-level WASH challenges remain. However, empirical evidence from Kakamega Municipality has not sufficiently integrated population density, infrastructure conditions and living conditions with the environmental, economic and social pathways through which these characteristics may be associated with household WASH services.

Existing studies have provided important evidence on particular settlement characteristics, environmental risks, economic constraints, social conditions and WASH outcomes. However, these dimensions are often examined separately or within major urban contexts such as Nairobi and Kisumu. Limited empirical work has examined how population density, infrastructure conditions and living conditions operate together through environmental, economic and social pathways in relation to household WASH accessibility, reliability and affordability in a secondary urban municipality. This study addresses this contextual and relational gap by examining the implications of informal settlement characteristics for household water and sanitation services in Kakamega Municipality, Kenya. It specifically examines population density, infrastructure conditions and living conditions and their environmental, economic and social pathways in relation to household WASH accessibility, reliability and affordability.

1.1 Research Objective

The objective of the study was to examine the implications of informal settlement characteristics for household water and sanitation services in Kakamega Municipality, Kenya, with a focus on accessibility, reliability and affordability.

II. LITERATURE REVIEW

2.1 Theoretical Review

This study was anchored on Urban Political Ecology (UPE) Theory, which examines how political, economic, social and ecological processes interact to shape urban environments and the distribution of resources and services (Swyngedouw, 1996; Heynen et al., 2006). UPE emphasizes that urban environmental inequalities are associated not only with ecological and technical conditions but also with governance, planning, resource allocation and power relations (Swyngedouw, 2004; Robbins, 2012). Urban infrastructure, including water, sanitation, drainage and waste-management systems, can therefore be understood as socio-natural arrangements shaped by interactions between material conditions and social and political processes (Kaika, 2005; Heynen et al., 2006).

In this study, UPE provides a framework for examining how population density, infrastructure conditions and living conditions are associated with household WASH services through environmental, economic and social pathways. Environmental pathways include waste-management constraints, flooding and contamination. Economic pathways include livelihood constraints and WASH-related financial burdens. Social pathways include insecurity, community

cooperation and perceived fairness in access. The framework situates household WASH conditions within the wider spatial and institutional processes through which urban infrastructure and services are organized and distributed.

2.2 Empirical Review

2.2.1 Population Density and Household WASH Services

Population density is a significant characteristic of informal settlements because the concentration of households within limited residential space increases demand for basic services and can place pressure on existing infrastructure. Ezeh et al. (2017) and Lilford et al. (2017) identify overcrowding, limited living space and inadequate urban infrastructure as common features of informal settlements. A similar study by Ren et al. (2020) showed that population density influences the spatial distribution and accessibility of urban services. These studies establish the importance of density as a spatial characteristic, but their approaches differ in their ability to explain household-level WASH experiences. Ren et al. (2020), for instance, used population and spatial data to examine the distribution of informal settlements in Nairobi, providing useful evidence of population concentration but not directly examining household water and sanitation outcomes.

Household-level studies provide a closer link between density and WASH conditions. Simiyu et al. (2019), using a cross-sectional survey in four informal settlements in Kisumu, examined household, housing, compound and neighborhood characteristics in relation to multidimensional deprivation. The study found extensive sharing of sanitation facilities, limited household water connections and unreliable water points. Similarly, (Corburn & Karanja, 2016) using household surveys, GIS mapping and focus-group discussions in Mathare, Nairobi, documented extensive sharing of water and sanitation facilities and spatial differences in access to facilities. These studies indicate that dense settlement environments can increase reliance on shared facilities creating spatial constraints on service accessibility. However, population density was not consistently operationalized as a specific explanatory variable, and the studies did not simultaneously examine its relationship with household WASH accessibility, reliability and affordability.

The existing studies provides important insights into population concentration and shared WASH facilities but leaves an empirical gap concerning the direct relationship between measurable settlement density and multiple dimensions of household WASH services. In addition, methodological gap exists because spatial studies demonstrate patterns of population concentration while household studies provide experiences of service deprivation without necessarily integrating density measures into the analysis. Furthermore, much of the Kenyan evidence is concentrated in cities like Nairobi and Kisumu, leaving limited evidence from secondary urban municipalities. The present study addresses these gaps by examining population density through household size and housing spacing, relating these characteristics to household WASH accessibility, reliability and affordability. Household survey evidences are combined with FGDs, KKIs and observation to explain the observed relationships. The study therefore contributes to the existing literature by providing household-level evidence on how measurable population-density characteristics of informal settlements are associated with multiple dimensions of WASH services within a secondary urban municipality. It extends evidence that has largely focused on metropolitan settings and single aspects of service deprivation

2.2.2 Infrastructure Conditions and Household WASH Services

Infrastructure conditions are central to household WASH service provision because the availability, condition and spatial distribution of water and sanitation facilities determine the physical opportunities through which households obtain services. Bishoge (2021) and Silvestri et al. (2018) identify inadequate infrastructure as a persistent constraint to WASH provision in underserved and informal urban settlements. Silvestri et al. (2018), in particular, demonstrate that WASH deficiencies are influenced not only by physical infrastructure but also by governance, land ownership, participation and socioeconomic conditions. This indicates that infrastructure deficits should be understood within their institutional and social context rather than as purely technical problems.

Household and spatial studies shows the consequences of infrastructure limitations for service access and reliability. Kim et al. (2022), examining informal settlements in Nairobi, combined household survey data with spatial information on WASH facilities. The study found that there is difficulties with water access and reliability, together with spatial variation in access to adequate water and sanitation facilities. Similarly, Simiyu et al. (2019) found limited household water connections, dependence on shared facilities and unreliable water points in Kisumu informal settlements. Furthermore, Corburn & Karanja (2016) showed that the location and condition of water and sanitation facilities affected the conditions under which residents accessed services. Chumo et al. (2023) showed that sanitation challenges extend along the sanitation value chain and involve physical, financial, technical, social and governance constraints. These studies shows that infrastructure deficiencies affect WASH accessibility and reliability, but they differ in their outcome measures and analytical approaches.

Despite this evidence, an empirical gap remains in understanding how water infrastructure, sanitation infrastructure and physical access routes collectively relate to household WASH services, rather than being examined as separate facilities or isolated spatial conditions. A methodological gap also exists because spatial approaches are

useful for identifying facility distribution, household surveys quantify service experiences, and qualitative approaches explain institutional and operational constraints, but these forms of evidence are not always integrated. Furthermore, existing Kenyan evidence is dominated by large metropolitan settlements, particularly Nairobi, limiting understanding of infrastructure-related WASH conditions in secondary municipalities. This study addresses these gaps by assessing water infrastructure, sanitation infrastructure and physical access routes as interconnected dimensions of infrastructure conditions, and relating them to household accessibility, reliability and affordability. It used household survey data complemented by FGDs, KIIs and observation. In doing so, the study contributes to the literature by integrating physical infrastructure conditions with household-level WASH outcomes. The study also demonstrates how the condition and accessibility of interconnected infrastructure shape the everyday experience of WASH services in an under-researched secondary urban municipality.

2.2.3 Living Conditions and Household WASH Services

Living conditions represent another important characteristic of informal settlements. The cleanliness of residential environments and the management of household and community waste influence the conditions under which water and sanitation services are accessed and used. Simiyu et al. (2019) found that poor sanitation, inadequate solid-waste disposal and environmental problems were important dimensions of deprivation in informal settlements in Kisumu. Similarly, Masimbe (2018) associated poor waste management and environmental conditions with water and sanitation challenges. In addition, Dickson-Gomez et al. (2023) found that inadequate environmental and waste-management conditions can contribute to WASH-related risks. These studies indicate that WASH conditions cannot be understood solely from the presence of water and sanitation facilities. The surrounding living environment also matters.

Moreover, Corburn & Karanja, (2016) provide evidence from Mathare, where inadequate sanitation, poor waste management and environmental conditions were associated with wider health and social consequences. Their use of household surveys, spatial mapping and focus groups enabled environmental conditions to be examined alongside residents' experiences. However, much of this literature approaches poor living conditions primarily as environmental-health or sanitation problems. Less attention was given to cleanliness and waste-management practices as dimensions of informal settlement characteristics and examining their relationship with household WASH accessibility, reliability and affordability.

These studies establish the importance of environmental and waste-management conditions, but a knowledge gap on how these conditions influence household-level WASH services remains. Methodologically, previous studies have frequently focused on health risks, contamination or sanitation conditions rather than simultaneously assessing WASH accessibility, reliability and affordability. This study addressed these gaps by operationalizing living conditions through cleanliness and waste-management practices and examining their relationship with household WASH outcomes. It further uses household survey findings alongside FGDs, KIIs and observation to examine how poor living conditions are experienced within the settlements and how they constrain the use and delivery of WASH services. In addition, the study contributes to existing literature by repositioning cleanliness and waste-management practices from being treated primarily as environmental-health concerns to being examined as integral characteristics of informal settlements that are related to household accessibility, reliability and affordability of WASH services in Kakamega Municipality.

2.2.4 Environmental, Economic and Social Pathways Linking Settlement Characteristics to WASH Services

The relationship between informal settlement characteristics and household WASH services operates through interconnected environmental, economic and social processes. Environmental conditions can affect WASH through waste accumulation, inadequate drainage, flooding and contamination. Douglas et al. (2008) demonstrated the environmental risks associated with inadequate drainage and waste management in African cities, while Corburn & Karanja (2016) linked inadequate sanitation and environmental conditions in Nairobi's informal settlements to contamination and related risks. These studies indicate that poor living conditions can constrain the effective use and maintenance of WASH facilities and increase exposure to environmental hazards.

Economic conditions provide another pathway. Limited employment and livelihood opportunities can reduce household purchasing capacity, particularly where households depend on informal or small-scale providers. Joshi et al. (2022), using a household survey in Nairobi informal settlements during the COVID-19 period, found that employment and business disruptions were associated with reduced ability to afford water. Joshi et al. (2023) further found that housing tenure and reliance on informal water services were associated with household water insecurity. These studies demonstrate the importance of economic and tenure conditions for WASH affordability and security, although they focus primarily on particular economic or tenure circumstances rather than the broader characteristics of informal settlements.

Social processes also shape access to shared WASH facilities. Corburn & Karanja (2016) identified social and gender-related consequences associated with inadequate sanitation, while Mitra et al. (2017) demonstrated the

importance of social cohesion, community participation and accountability in intervention outcomes in Kibera. Chumo et al. (2023) similarly found that trust, reciprocity, social networks and information channels formed part of the ways through which residents and sanitation workers responded to sanitation challenges. Such evidence indicates that physical infrastructure alone does not determine WASH outcomes; insecurity, cooperation and the distribution of access among users can influence how services are actually experienced.

Previous studies demonstrate that environmental, economic and social processes influence WASH conditions, however, these pathways have generally been examined separately. This creates an analytical and knowledge gap concerning how they connect settlement characteristics to household WASH outcomes. Environmental studies have emphasized waste, flooding and contamination. Economic studies have focused on employment, income, tenure or water costs. Social studies have considered insecurity, participation and collective action. Evidence integrating these processes as pathways linking population density, infrastructure conditions and living conditions to the three household WASH dimensions of accessibility, reliability and affordability remains limited. This study addressed these gaps by treating environmental, economic and social conditions explicitly as pathways rather than additional independent variables. Environmental processes are examined through waste-management constraints, flooding and drainage and contamination. Economic processes were examined through livelihood and employment conditions and the financial burden of WASH. Social processes were examined through insecurity, community cooperation and perceived fairness of access. These relationships are examined using household-level quantitative evidences. They were then interpreted through FGDs, KIIs and observation. The study contributes to existing literature by providing an integrated pathway-based explanation of how population density, infrastructure conditions and living conditions are connected to household WASH accessibility, reliability and affordability through environmental, economic and social processes. It thereby links settlement characteristics to WASH outcomes within the context of a secondary urban municipality in Kenya.

III. METHODOLOGY

3.1 Research Design

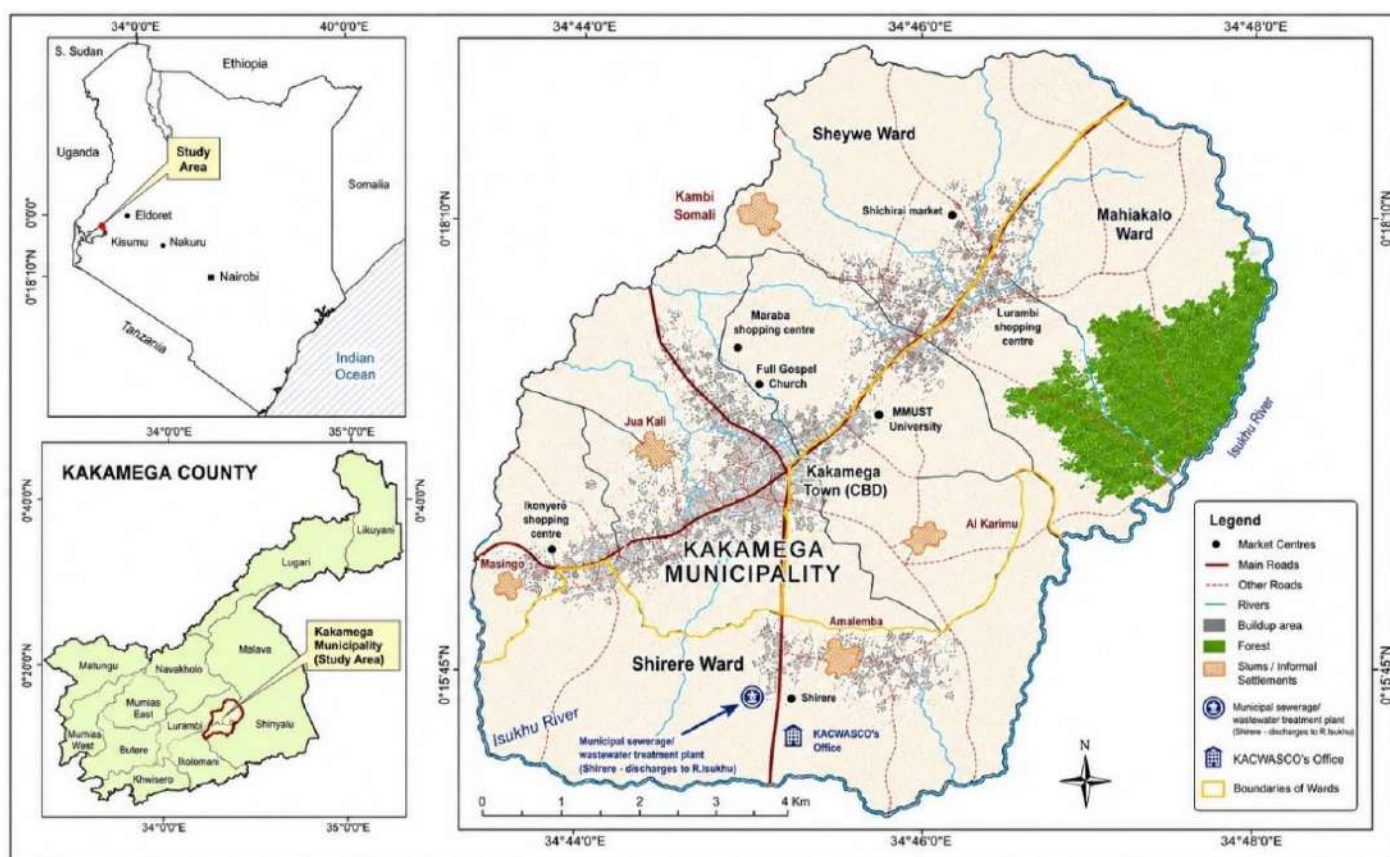
The study adopted a cross-sectional research design using mixed methods. Quantitative data were collected through structured household questionnaires. On other hand, qualitative data were obtained through key informant interviews (KIIs), focus group discussions (FGDs), field observations and document analysis. The design was appropriate for assessing existing settlement conditions and examining associations among settlement characteristics, household WASH services and related environmental, economic and social conditions without manipulating the study variables (Creswell & Creswell, 2018; Setia, 2016).

Quantitative data were analyzed using frequencies, percentages, the Chi-square test of independence and Cramer's V, whereas qualitative data were analyzed thematically. The two strands were integrated during interpretation to provide contextual explanations and triangulation of the findings. Given the cross-sectional nature of the study, the results were interpreted as associations rather than definitive causal relationships (Setia, 2016).

3.2 Study Area

The study was conducted in Kakamega Municipality, Kakamega County, Kenya. According to County Government of Kakamega (2025), the municipality is approximately 30 km north of the Equator, 500 km west of Nairobi and 52 km north of Kisumu. It lies at approximately 0.2833°N and 35.8667°E, at an elevation of about 1,575 m above sea level. It is an important commercial and administrative Centre in western Kenya, characterized by residential, commercial and institutional activities. The study focused on five informal settlements: Amalemba, Kambi Somali, Makaburini/Alkarim, Masingo and Juakali.

The municipality experiences a tropical climate with annual rainfall ranging from approximately 1,280.1 to 2,214.1 mm (County Government of Kakamega, 2025). River Isiukhu passes through the municipality, while informal settlements commonly rely on pit latrines, open drainage and informal solid-waste disposal systems. These physical and infrastructural conditions, together with population concentration and diverse urban economic activities, provide an appropriate setting for examining how informal settlement characteristics relate to household water and sanitation services. The spatial distribution of the study settlements is presented in Figure 2.

**Figure 2**

Map of Kakamega Municipality Showing Informal Settlements, Water and Sanitation Facilities

Source: Author's compilation based on Survey of Kenya (2010)

3.3 Target Population

The study targeted 1,202 households across five selected informal settlements in Kakamega Municipality: Amalemba, Kambi Somali, Makaburini/Alkarim, Masingo and Juakali. The household population was based on records from the County Government of Kakamega, Department of Physical and Urban Planning (2026). In addition, key informants (KIIs) were drawn from institutions directly involved in water and sanitation provision, public health, and settlement planning and management. In particular, KIIs came from the Kakamega County Water and Sanitation Company (KACWASCO), the County Department of Public Health, and the Department of Physical and Urban Planning.

3.4 Sampling and Sample Size

Kakamega Municipality and the five informal settlements were purposively selected because they provided information-rich settings for examining the characteristics of informal settlements and household water and sanitation services. The five settlements constituted the sampling strata, and the household sample was proportionately allocated according to the number of households in each settlement. Household heads were subsequently selected using simple random sampling. Household heads were targeted because of their role in household-level decisions concerning water and sanitation resources. Key informants were purposively selected based on their institutional roles and knowledge, with snowball sampling used to identify additional relevant informants.

The household sample size was determined using the Krejcie and Morgan (1970) approach for finite populations. From a target population of 1,202 households, a sample of 291 households was obtained at a 95% confidence level and 5% margin of error. The sample comprised 27 households from Amalemba, 39 from Kambi Somali, 61 from Makaburini/Alkarim, 116 from Masingo and 48 from Juakali. The qualitative component comprised four key informants drawn from KACWASCO, the County Department of Public Health, and the Department of Physical and Urban Planning, as well as five focus group discussions, one in each selected settlement.

3.5 Data Collection Instruments and Procedures

Data were collected using structured household questionnaires, an observation checklist, semi-structured key informant interview (KII) schedules, focus group discussion (FGD) guides and document review. The questionnaire was administered through face-to-face interviews and included open- and closed-ended items. The observation checklist

assessed population density, infrastructure conditions and living conditions, with observation items rated on a three-point scale ranging from poor to good.

Semi-structured KIIs were conducted with four institutional informants, while five FGDs, one in each study settlement, involved 65 participants. The KIIs examined institutional perspectives on water, sanitation, public health and urban planning. FGDs explored residents' experiences of settlement characteristics and household WASH services. Discussions and interviews were conducted with participants' consent, audio-recorded where permitted and transcribed. Relevant policy, legal, planning and institutional documents were also reviewed to provide contextual evidence and support triangulation of findings.

3.6 Data Analysis

The study adopted a mixed-methods approach in which quantitative and qualitative data were analyzed separately and integrated during interpretation. Quantitative data from the household questionnaires were coded, cleaned and analyzed using the Statistical Package for the Social Sciences (SPSS). Frequencies and percentages were used to summarize the distribution of study variables and were presented primarily in tables. The Chi-square test of independence was used to examine associations between informal settlement characteristics and household water and sanitation service outcomes. Where statistically significant associations were identified, Cramer's V was calculated to determine the strength of association. Statistical tests were conducted at a 95% confidence level, with statistical significance established at $p < 0.05$.

Qualitative data from KIIs, FGDs, and document analysis and field observations were transcribed, coded and analyzed thematically. The analysis involved identifying meaningful statements, grouping related codes and developing themes corresponding to the study objectives. Qualitative evidence was triangulated with quantitative results to provide contextual explanations and corroboration of the statistical findings.

3.7 Ethical Considerations

Ethical and administrative clearance was obtained from the Directorate of Postgraduate Studies at Masinde Muliro University of Science and Technology (MMUST). It was followed by a research permit from National Commission for Science, Technology and Innovation (NACOSTI) and relevant authorization from county authorities. Before participation, respondents were informed about the purpose of the study and their consent was obtained. Participation was voluntary, and respondents were informed of their right to decline participation or withdraw at any stage. Confidentiality and anonymity were maintained by avoiding the collection of personal identifiers and using codes during data processing and analysis. Electronic research data were securely stored using password-protected devices and controlled-access storage and were used solely for academic purposes

IV. FINDINGS & DISCUSSION

4.1 Characteristics of Informal Settlements and Household WASH Conditions

Table 1 shows that the informal settlements were characterized by concentrated household occupation, closely spaced housing, inadequate WASH infrastructure and poor environmental conditions. Most households (57.0%) comprised 4-6 members, while 72.2% reported closely or very closely spaced housing. Water and sanitation infrastructure were rated poor or very poor by 72.5% and 73.2% of households, respectively, while 64.9% reported poor or very poor physical access routes. Environmental conditions were particularly constrained, with 80.5% describing their surroundings as dirty or very dirty and 93.2% rating solid-waste management as poor or very poor. These findings demonstrate that the study settlements were characterized by interacting spatial, infrastructural and environmental deficiencies. Similar relationships between settlement conditions, infrastructure deficits and deprivation have been documented in informal settlements in Sub-Saharan Africa (Ezeh et al., 2017). The findings highlight how the organization of urban space and uneven provision of infrastructure can be associated with differentiated access to essential urban services as stated in UPE (Swyngedouw, 1996; Heynen et al., 2006).

Table 1*Characteristics of Informal Settlements in Kakamega Municipality (%)*

Characteristic	Category	Number of Respondents (%)
Household size	1–3 people	14.8
	4–6 people	57.0
	7–9 people	21.0
	10 or more	7.2
Housing spacing	Very closely spaced	33.7
	Closely spaced	38.5
	Moderately spaced	22.3
	Widely spaced	5.5
Water infrastructure	Very good/Good	5.5
	Fair	22.0
	Poor/Very poor	72.5
Sanitation infrastructure	Very good/Good	5.5
	Fair	21.0
	Poor/Very poor	73.2
Physical access	Very good/Good	13.1
	Fair	22.0
	Poor/Very poor	64.9
Environmental cleanliness	Very clean/Clean	19.6
	Dirty/Very dirty	80.5
Solid-waste management	Very good/Good	6.8
	Poor/Very poor	93.2

**Plate 1***Closely Spaced Housing in an Informal Settlement in Kakamega Municipality*



Plate 2
Dilapidated Pit Latrine in an Informal Settlement in Kakamega Municipality

4.2 Typology of Informal Settlements

Table 2 shows variation in deprivation across the five settlements. Amalemba and Masingo were classified as moderately deprived, whereas Kambi Somali, Makaburini/Alkarim and Juakali were classified as highly deprived. The typology reflects differences in population density, infrastructure conditions and living conditions. The variation demonstrates that informal settlements within the same municipality are not homogeneous. Differences in settlement organization and infrastructure conditions may therefore be relevant when examining household WASH outcomes. Similar spatial differences in physical and socioeconomic conditions in informal settlements have been documented by Wekesa et al., (2011). From a UPE perspective, this differentiation can be understood in relation to the uneven spatial distribution of infrastructure and environmental services within urban areas (Swyngedouw, 1996; Heynen et al., 2006). The typology therefore provides contextual evidence for examining the environmental, economic and social pathways associated with household WASH services.

Table 2
Typology of Informal Settlements in Kakamega Municipality

Settlement	Population density	Infrastructure conditions	Living conditions	Overall typology
Amalemba	High	Moderate	Moderate	Moderately deprived
Kambi Somali	High	Poor	Poor	Highly deprived
Makaburini/Alkarim	High	Poor	Poor	Highly deprived
Masingo	Moderate	Moderate	Moderate	Moderately deprived
Juakali	High	Poor	Poor	Highly deprived

**Plate 3**

Physical and Environmental Characteristics of a Highly Deprived Informal Settlement in Kakamega Municipality

4.3 Environmental Pathways and Household WASH Services

Table 3 shows substantial environmental pressures within the settlements. Improper solid-waste disposal, flooding and poor drainage, and water-source contamination affected households to a great or moderate extent in 93.1%, 83.9% and 85.2% of cases, respectively. These findings indicate that environmental constraints were widespread, particularly those related to waste management and drainage.

Table 3

Environmental Implications of Informal Settlements (%)

Environmental implication	Great extent	Moderate extent	Small extent	Not at all
Improper solid-waste disposal	52.6	40.5	5.2	1.7
Flooding and poor drainage	50.2	33.7	14.8	1.4
Water-source contamination	45.0	40.2	12.7	2.1

Table 4 shows statistically significant associations between all three environmental pathways and household WASH services. Improper solid-waste disposal had a strong association with household WASH services ($\chi^2 = 196.45$, $df = 2$, $p < .001$, $V = .79$), as did flooding and poor drainage ($\chi^2 = 188.08$, $df = 2$, $p < .001$, $V = .77$). Water-source contamination was also significantly associated with household WASH services, although the association was weak ($\chi^2 = 9.38$, $df = 2$, $p = .009$, $V = .17$). These findings are consistent with evidence linking inadequate waste management, drainage and flooding with WASH challenges in informal settlements (Douglas et al., 2008; Juma et al., 2023; Lebu et al., 2024). In Kakamega, Okari (2019) similarly documented inadequate waste-disposal systems and poorly maintained sanitation facilities in an informal settlement. From a UPE perspective, the findings illustrate how environmental conditions are connected to the spatial organization of settlements and the provision and maintenance of urban infrastructure (Swyngedouw, 1996; Robbins, 2012). Environmental conditions therefore constituted an important pathway through which informal settlement characteristics were associated with household WASH services.

Table 4

Association between Environmental Implications and Household WASH Services

Environmental pathway	χ^2	df	p-value	Cramer's V	Interpretation
Improper solid-waste disposal	196.45	2	<.001	0.79	Strong
Flooding and poor drainage	188.08	2	<.001	0.77	Strong
Water-source contamination	9.38	2	.009	0.17	Weak

Note: $N = 291$ households. χ^2 = Chi-square statistic; df = degrees of freedom.

4.4 Economic Pathways and Household WASH Services

Table 5 shows that settlement conditions had substantial economic implications for households. Settlement conditions affected livelihood activities to a great or moderate extent for 62.6% of respondents, while 90.0% considered employment and livelihood opportunities inadequate or very inadequate. In addition, 77.7% reported that living conditions increased household economic burden to a great or moderate extent.

Table 5

Economic Implications of Informal Settlements in Kakamega Municipality (%)

Economic implication	Category	Number of Respondents (%)
Settlement conditions affecting livelihood activities	Great extent	33.7
	Moderate extent	28.9
	Small extent	23.0
	Not at all	14.4
Employment and livelihood opportunities	Very adequate	2.1
	Adequate	7.9
	Inadequate	42.6
	Very inadequate	47.4
Living conditions increasing household economic burden	Great extent	42.6
	Moderate extent	35.1
	Small extent	18.2
	Not at all	4.1

Table 6 shows statistically significant associations between all three economic pathways and household WASH services ($p < .001$). Settlement conditions affecting livelihood activities had the strongest association ($\chi^2 = 84.36$, $df = 6$, $V = .38$), followed by household economic burden ($\chi^2 = 46.81$, $df = 6$, $V = .29$) and employment and livelihood opportunities ($\chi^2 = 28.94$, $df = 6$, $V = .22$). All three associations were moderate in strength. The findings are consistent with evidence that economic circumstances and employment conditions are associated with water insecurity and affordability in informal settlements (Adams, 2018; Joshi et al., 2022). Dependence on alternative water providers where formal provision is inadequate may also increase household expenditure (Masinde et al., 2024a; Masinde et al., 2024b). From a UPE perspective, these relationships can be interpreted in the context of uneven urban service provision, whereby households that are less well integrated into formal infrastructure networks may face additional economic costs in obtaining essential services (Swyngedouw, 1996; Heynen et al., 2006). Economic conditions therefore represented a second pathway through which informal settlement conditions were associated with household WASH services.

Table 6

Association between Economic Implications and Household WASH Services

Economic pathway	χ^2	df	p -value	Cramer's V	Interpretation
Settlement conditions affecting livelihood activities	84.36	6	<0.001	0.38	Moderate
Employment and livelihood opportunities	28.94	6	<0.001	0.22	Moderate
Living conditions increasing economic burden	46.81	6	<0.001	0.29	Moderate

Note: $N = 291$ households

4.5 Social Pathways and Household WASH Services

Table 7 shows a mixed social environment within the settlements. Insecurity affected daily activities to a great or moderate extent for 77.3% of households, while 74.6% reported high or very high community cooperation. In contrast, 83.5% indicated that fairness in access to community services and facilities was achieved only to a small extent or not at all. These findings indicate that community cooperation coexisted with insecurity and perceived inequalities in access to services.

Table 7*Social Implications of Informal Settlements in Kakamega Municipality (%)*

Social implication	Category	Number of Respondents (%)
Insecurity affecting daily activities	Great extent	44.0
	Moderate extent	33.3
	Small extent	17.5
	Not at all	5.2
Community cooperation	Very high	42.3
	High	32.3
	Low	22.0
	Very low	3.4
Fairness in access to community services	Great extent	5.8
	Moderate extent	10.7
	Small extent	33.3
	Not at all	50.2

Table 8 shows that all three social pathways were significantly associated with household WASH services ($p < .001$). Community cooperation had the strongest association ($\chi^2 = 102.45$, $df = 6$, $V = .42$), followed by fairness in access to community services ($\chi^2 = 86.74$, $df = 6$, $V = .39$) and insecurity ($\chi^2 = 58.62$, $df = 6$, $V = .32$). The associations involving fairness and insecurity were moderate, while community cooperation showed a strong association. The findings are consistent with research emphasizing community participation and social accountability in improving WASH and settlement-upgrading interventions (Schouten & Mathenge, 2010; Corburn & Sverdluk, 2017; Mitra et al., 2017). From a UPE perspective, the coexistence of community cooperation and perceived inequality illustrates the interaction between community agency and uneven access to urban resources. Social conditions therefore constituted a third pathway through which informal settlement characteristics were associated with household WASH services.

Table 8*Association between Social Implications and Household WASH Services*

Social pathway	χ^2	df	p-value	Cramer's V	Interpretation
Insecurity affecting daily activities	58.62	6	<0.001	0.32	Moderate
Community cooperation	102.45	6	<0.001	0.42	Strong
Fairness in access to community services	86.74	6	<0.001	0.39	Moderate

Note: $N = 291$ households

4.6 Household Water and Sanitation Services

4.6.1 Accessibility

Table 9 shows substantial constraints in household WASH accessibility. Overall, 72.5% of households required more than 30 minutes to obtain water, including 40.9% who required more than one hour. Access to water when needed was difficult or very difficult for 69.8% of households, while 66.0% reported difficult or very difficult access to sanitation facilities. Key informants and FGD participants similarly identified long distances, congestion, inadequate facilities and unplanned access routes as important accessibility challenges. These findings are consistent with evidence of WASH accessibility limitations in Nairobi's informal settlements (Kim et al., 2022) and the need for alternative and transitional infrastructure where conventional networks have not kept pace with settlement growth (Colombo et al., 2025). From a UPE perspective, these accessibility constraints can be understood in relation to the uneven spatial distribution of infrastructure and services. Settlement organization and patterns of infrastructure provision may therefore be associated with households' ability to reach WASH facilities.

Table 9*Accessibility of Household WASH Services (%)*

Indicator	Category	Number of Respondents (%)
Time to obtain water	Less than 15 minutes	8.9
	15–30 minutes	18.6
	31–60 minutes	31.6
	More than 60 minutes	40.9
Access to water when needed	Very easy	12.7
	Easy	17.5
	Difficult	31.3
	Very difficult	38.5
Access to sanitation facility	Very easy	14.4
	Easy	19.6
	Difficult	30.9
	Very difficult	35.1

4.6.2 Reliability

Table 10 shows substantial constraints in WASH reliability. Only 30.2% of households reported that water was always available or available most of the time, compared with 69.7% who reported that water was available only sometimes or rarely. WASH service interruptions were also widespread, with 95.2% reporting that interruptions occurred sometimes or often. Qualitative evidence similarly indicated intermittent water availability and reliance on alternative sources during interruptions. Field observations, including residents obtaining water from streams, further illustrated coping with unreliable supply. The findings indicate that the presence of infrastructure does not necessarily translate into dependable service delivery. Colombo et al. (2025) similarly demonstrated that infrastructure arrangements influence continuity of water supply in Nairobi's informal settlements. From a UPE perspective, reliability can be understood not only in terms of infrastructure presence but also in relation to the spatial and institutional organization of service provision. The findings therefore demonstrate that household WASH reliability is an important dimension of service inequality in informal settlements.

Table 10*Reliability of Household WASH Services (%)*

Indicator	Category	Number of Respondents (%)
Water availability	Always	13.4
	Most of the time	16.8
	Sometimes	30.2
	Rarely	39.5
WASH service interruptions	Never	0.7
	Rarely	4.1
	Sometimes	33.0
	Often	62.2

4.6.2 Affordability of Household Water and Sanitation Services

Table 11 shows that affordability was another substantial constraint. Monthly water expenditure exceeded KES 1,000 for 76.3% of households, including 41.6% who spent more than KES 1,500. Although 60.8% reported no monthly sanitation expenditure, 64.6% perceived WASH services as unaffordable or very unaffordable. The absence of direct sanitation expenditure should not necessarily be interpreted as evidence of affordability because households may use shared or communal facilities and may incur indirect or periodic costs. The relatively high expenditure on water and perceived unaffordability suggest that some households may rely on alternative supply arrangements where formal services are inadequate or unreliable. Similar relationships between socioeconomic circumstances and water insecurity have been documented in Nairobi and other African informal settlements (Adams, 2018; Kim *et al.*, 2022). From a UPE perspective, affordability reflects how the economic costs of urban service provision may be distributed unevenly across urban populations. Households that are poorly integrated into formal WASH networks may face additional costs through alternative service arrangements. Affordability therefore represents an important dimension of household WASH inequality in informal settlements.

Table 11*Affordability of Household WASH Services (%)*

Indicator	Category	Number of Respondents (%)
Monthly water expenditure	Less than KES 500	6.2
	KES 500–1,000	17.5
	KES 1,001–1,500	34.7
	More than KES 1,500	41.6
Monthly sanitation expenditure	No expenditure	60.8
	Less than KES 500	15.1
	KES 500–1,000	13.4
	More than KES 1,000	10.7
Perceived WASH affordability	Very affordable	15.5
	Affordable	19.9
	Unaffordable	38.8
	Very unaffordable	25.8

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

The study found that informal settlements in Kakamega Municipality were characterized by concentrated household occupation, closely spaced housing, inadequate infrastructure and poor environmental conditions. These characteristics were associated with household WASH services through environmental, economic and social pathways. Environmental pathways showed the strongest associations, particularly improper solid-waste disposal and flooding and poor drainage. Economic pathways were also significantly associated with household WASH services, with settlement conditions affecting livelihood activities showing the strongest economic association. Social pathways were similarly significant, with community cooperation showing the strongest social association. These relationships were reflected in substantial constraints in WASH accessibility, reliability and affordability. These findings indicate that household WASH conditions in Kakamega's informal settlements are associated with interconnected settlement conditions, through environmental, economic and social pathways.

5.2. Recommendations

The County Government of Kakamega should prioritize integrated upgrading of informal settlements, particularly improvements in water supply, sanitation, drainage and physical access infrastructure in highly deprived settlements. Environmental management should be strengthened through improved solid-waste collection, drainage maintenance and measures to reduce localized flooding and associated environmental risks. WASH service providers and other stakeholders should expand reliable and affordable service coverage while considering the economic burden experienced by households that depend on alternative service arrangements. Community participation should be strengthened in WASH planning, facility management and settlement-improvement initiatives to build on existing community cooperation while addressing perceived inequalities in access. Land-use planning and settlement regularization should also be strengthened to support infrastructure investment and more equitable provision of WASH services.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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