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Original Article

Effects of Climate Change-Induced Flooding on Onsite Sanitation Services: A Case Study of Kanyama, Compound in Lusaka, Zambia

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Climate Change, Flooding, Onsite Sanitation, Sustainability Model.

ABSTRACT

The study underscores the absence of a comprehensive assessment of flooding effects on onsite sanitation systems in Kanyama, exacerbating existing issues like inadequate facilities, poor maintenance, and improper waste management. Conducting both qualitative and quantitative methods, the research engaged 210 respondents from six wards in Kanyama, using systematic random sampling for households and purposive sampling for key informants. Employing predictive models (Root Mean Square Error and R-squared values) in SPSS Version 22, the findings revealed negative effects on onsite sanitation systems, including contamination of water, infrastructure damage, and overflowing of pit latrines/septic tanks. Key statistics include 68% of respondents witnessing temperature changes, 63% understanding climate change, and 73% acknowledging changes in rainfall patterns. For flooding, 72% observed increased floods, with a statistical analysis yielding R-squared values of 0.431, 0.427, and 0.373 for water contamination, infrastructure damage, and overflowing of pit latrines/septic tanks, respectively. These values represent the percentage of variation explained by flood-related variables. Chi-squared statistics values of 234.16, 214.564, and 152.132 highlight a significant effect of flood-related variables on observed outcomes. Qualitative data identified themes such as awareness of climate change effects, diverse beliefs, varying community awareness, and the need for tailored education. The study proposed a Sustainability model, emphasizing drainage systems, awareness campaigns, infrastructure development, waste management, and partnerships to enhance community resilience against climate change-induced flooding.

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INTRODUCTION

The prevalent effects of climate change on human health and the environment amplify the significance of effective sanitation systems, especially in densely populated peri-urban areas where risks from unsafe excreta disposal are heightened due to increased volumes and exposure probabilities. Climate change hinders achieving universal access to safely managed sanitation, making the process more costly and slower (UNESCO, 2017). The challenges of collecting, treating, and disposing of escalating wastewater quantities persist in developed and developing countries, exacerbated by population growth, urbanization, and industrialization. The far-reaching effects of climate change extend beyond environmental concerns, influencing the vulnerability of social and socioeconomic systems leading to heightened issues such as social discrimination, deprivation, dissatisfaction, unacceptability, and increased migration (WaterAid, 2012).

Climate change, notably through increasing occurrences of flooding, critically affects water supply quality and utilization, disrupting water supplies and sanitation facilities, thus risking contamination of water sources and endangering millions of lives (WHO, 2018). This issue is particularly acute in flood-prone regions with limited access to water and sanitation, heightening the risk of waterborne diseases and rendering populations exceptionally vulnerable. The increasing frequency of floods, alongside more frequent droughts and higher average temperatures, causing severe water stress, highlight the pronounced impact of climate change on urban water supply and sanitation sectors. Studies have explored the resilience of sanitation technologies, emphasizing the need for enhanced access to sustainable water sources and improved sanitation in changing environments (Mishra et al., 2021)

In places like the Kanyama compound in Lusaka, Zambia, where centralized sanitation infrastructure is absent, climate change exacerbates existing challenges related to sanitation facilities, maintenance, and waste management, impacting public health and the environment. Kanyama, with its flat and rocky terrain, experiences severe flooding, relying on boreholes and kiosks for water provision and pit latrines for sanitation amidst projections of increased temperatures, rainfall, and extreme weather events due to climate change (Aldos et al., 2022).

Despite the scholarly work prevalent globally on the consequences of climate change-induced floodings, there has not been a comprehensive assessment of the evidence base for the effects of such floodings on the range of peri-urban onsite sanitation services or components of such services in the Kanyama compound of Zambia. Thus, the research sought to assess the effects of climate change-induced flooding on onsite sanitation services in the Kanyama compound.

MATERIALS AND METHODS

Study Area

The Kanyama settlement, legalized in 1999 under the Statutory and Improvement Areas Act, is 7 km west of Lusaka's Central Business District, bordered by Los Angeles and Mumbwa roads. With a population density of approximately 8,636 people/km² in 2010 and a current population of 525,902, Kanyama is characterized by its substantial informal housing and reliance on onsite sanitation facilities. The settlement's proximity to the CBD attracts migrants seeking employment, contributing to its high population density. However, Kanyama faces significant

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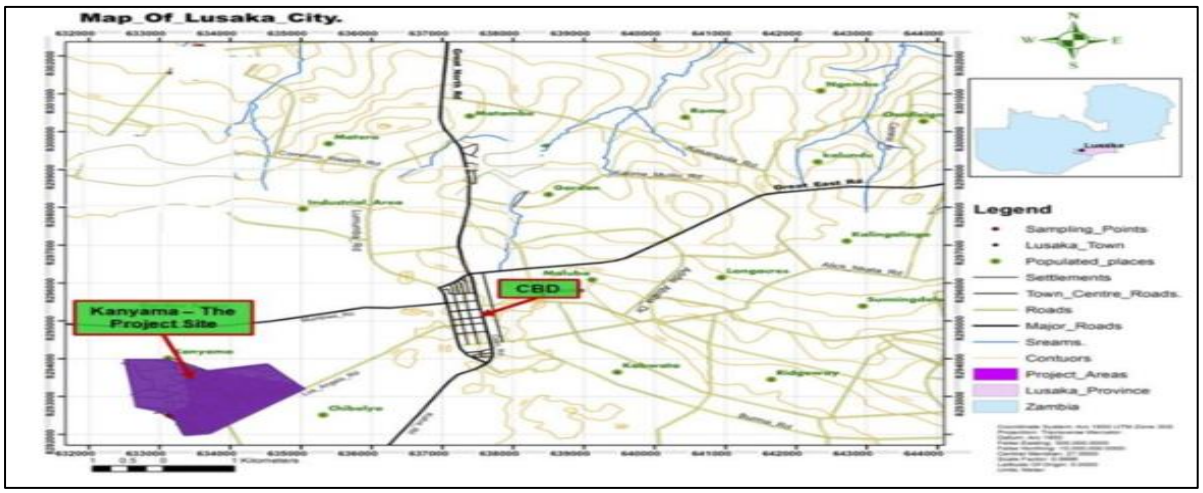
challenges, including poor access to sanitation, ineffective faecal sludge management (FSM) systems, and a geology that exacerbates waterborne disease outbreaks during the rainy season. The presence of an FSM enterprise and recent flash floods made Kanyama a pertinent study area, where the Kanyama Water Trust collaborates with Lusaka City Council to offer desludging services

Figure 1: Research site,



Source (Chamisa, 2022).

Research Design

This study adopted a mixed-methods research design to investigate the effects of Flooding on Onsite Sanitation Services Related to Climate Change in the Kanyama compound, Lusaka District. The research focused on household heads, utilizing systematic random sampling to select 210 respondents across all six wards. This mixed-methods approach comprehensively explores the research topic, combining quantitative precision with qualitative depth (Guetterman, T. C., & Fetters, M. D. (2018). By integrating these methodologies, the study enhances the credibility and richness of its findings, contributing valuable insights into the intricate dynamics between climate change-induced flooding and onsite sanitation services. Through systematic data collection and rigorous analysis, the research aims to inform effective strategies and policies, benefiting the local context in Kanyama and providing valuable lessons for similar vulnerable communities globally.

Sampling Procedure and Sample Size

This research employed a systematic random sampling for the households and purposive sampling of key targeted stakeholders' key informant interviews for both qualitative and quantitative data. An estimated population of over 525,902 people live in Kanyama. Using the sample size calculation formular below, 214 households were surveyed, and 5 stakeholders implementing sanitation in Kanyama were interviewed. The household heads were targeted since they are responsible for the well-being of their families. Systematic random sampling was used to select the houses to be sampled in all six wards and household heads for the research instruments. In selecting the houses to be sampled, all wards were listed down randomly, and every 6th house on the list was chosen for sampling. The formula below was used to arrive at the sample size of 214.

$$N = \frac{z^2.p.q}{e^2}$$

Given values: N (population size) = 525,902; e (margin of error) = 0.067 (6.7% expressed as a decimal); p=0.5; q=1−p=0.5; Z for a 95% confidence level is approximately 1.96

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Now, substitute these values into the formula.

$$n = \frac{(1.96)^2 * 0.5 * 0.5}{(0.06)^2} = 214$$

Therefore, the sample size (n) needed for a population of 525,902 with a margin of error of 6.7% is approximately 214.

This research returned a response rate of over 98% (210 out of 214), considered very high in survey research, indicating a successful data collection process and lending credibility to the study's outcomes. Such a high response rate indicates the respondents' engagement and interest in the subject matter, which enhances the quality of the collected data. Additionally, most statistical techniques are robust enough to accommodate this level of non-response without compromising the integrity of the analysis. This response rate reinforces the generalizability of the study's conclusions and signifies that the findings reflect the broader population's perspectives and experiences.

Data Collection Tool

Table 1: data collection tools

Data Collection Tool	Method of Collection	Tool of Collection
Primary data	Structured questionnaire	Guided schedules
	In-depth interviews	Guided schedules
	Direct observations	Note taking Photographs
	Participation observations	Note taking. Photographs
Secondary data	Documents, reports, journals, magazine, newspapers, and thesis.	• Reading • Reviewing

Data Collection

Qualitative data was collected through in-depth interviews with key informants from Kanyama Water Trust (KWT), Lusaka City Council (LCC), Lusaka Water and Sanitation Company (LWSCO), Chazanga Water Trust (CWT), and Plan International Zambia, including local government officials, community leaders, and representatives of non-governmental organizations working in the sanitation sector in Kanyama.

Quantitative data was collected through a household survey of 210 households through a questionnaire, while the other data was collected from the Meteorological Department of Zambia. The survey collected information on household demographics, sanitation facilities, water supply, waste management, and the effects of climate change on onsite sanitation service delivery. Using the structure under the Ministry of Health (Kanyama level Hospital), the EHT and the hospital volunteers administered the questionnaire at the household level.

Data Analysis

In this study, the researchers employed a comprehensive approach to data analysis, combining qualitative and quantitative methods for a deeper insight into the subject matter. Qualitative data was meticulously analyzed using thematic analysis with the Delve package, revealing recurring themes and narratives within the responses. Concurrently, quantitative data from a survey was rigorously analyzed using SPSS Version 22 and further examined through Principal Component Analysis (PCA) to simplify data relationships by reducing dimensionality. The factors identified via PCA were then analyzed using the Seemingly Unrelated Regression (SUR) model, uncovering complex interrelations among them. This integration of qualitative and quantitative analyses, alongside advanced statistical methodologies, provided a holistic and nuanced understanding of the research topic, enriching the findings and deepening the comprehension of the effects of climate change-induced flooding on onsite sanitation services in Kanyama.

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RESULTS

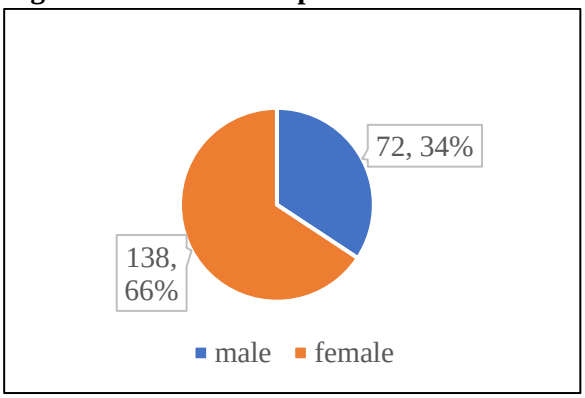
Demographic Characteristics and General Views of Respondents

The socioeconomic characteristics such as gender, educational level, household income, duration of respondents' stay, family size, type of sanitation facility, number of people using sanitation facility, and frequency of emptying SF, including general views of respondents on challenges of using onsite SF, waterborne disease prevalence changes, change in rainfall patterns, increased flooding experiences, and change in temperature patterns were investigated to possess the appropriate understanding of respondents and further depicted through descriptive statistics. These were studied or undertaken to provide the general characteristics of the inhabitants of the research area.

Gender Distribution

This is an essential demographic characteristic in research that helps underscore the distribution of respondents. The chart below indicates the distribution of respondents in terms of gender.

Figure 2: Gender of respondents

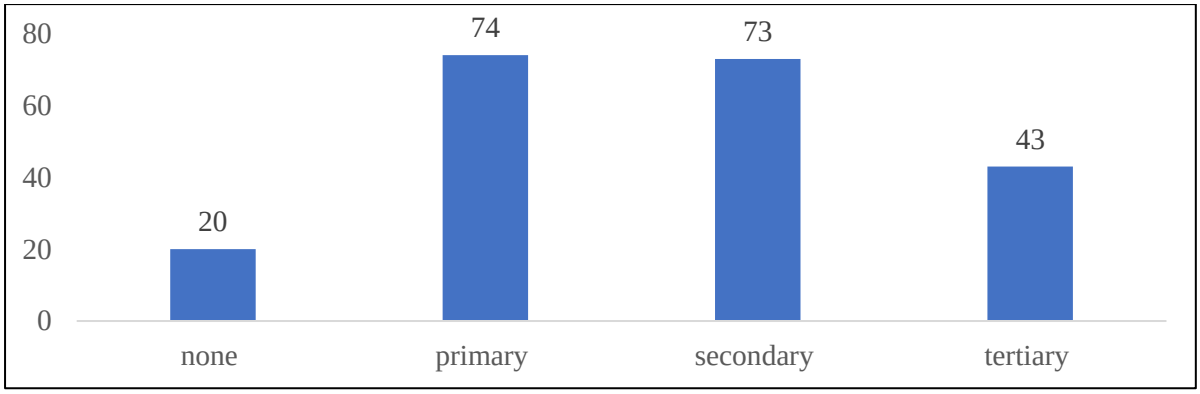


Source: (Filed data 2023)

Educational Levels

Education level is a key demographic in this research, influencing respondents' awareness of flood impacts on sanitation, as depicted in *Figure 3*. Higher education correlates with a better understanding of flooding and sanitation dynamics. Analyzing educational backgrounds sheds light on community resilience and adaptation to climate change challenges, enhancing comprehension of factors affecting sanitation service delivery in Kanyama Compound.

Figure 3: Education levels of respondents



Source: (Filed data 2023)

Household Income and Residence Duration

Figure 4 highlights the relevance of household income and residence duration in the Kanyama Compound, offering insights into the community's socioeconomic stability. Household income determines the capacity for adapting to and recovering from flood impacts on sanitation, with higher income enabling investment in resilient infrastructure. Residence duration reflects community attachment and familiarity, whereas longer stays may indicate a better understanding of local challenges and a history of adaptation to flooding. These demographics are crucial for a comprehensive analysis of socioeconomic context and resilience against climate change effects on sanitation services

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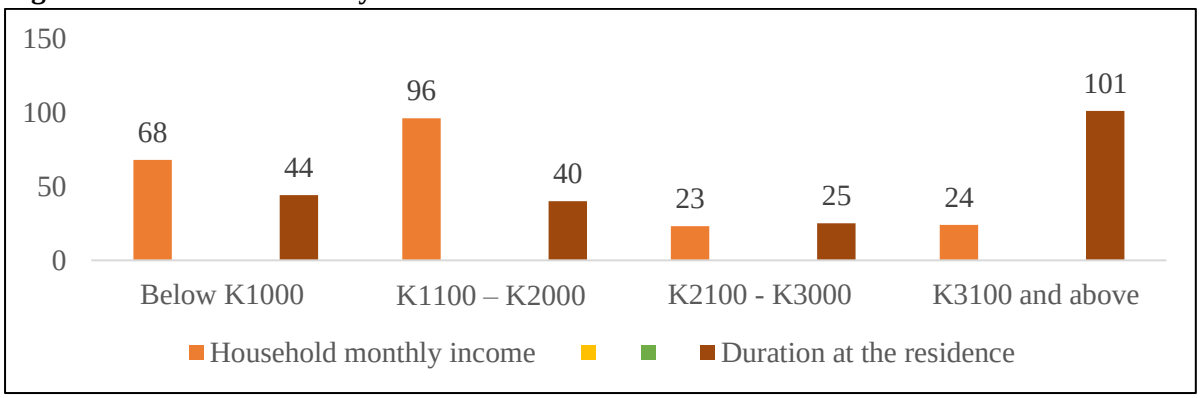
Figure 4: Household monthly income and residence duration

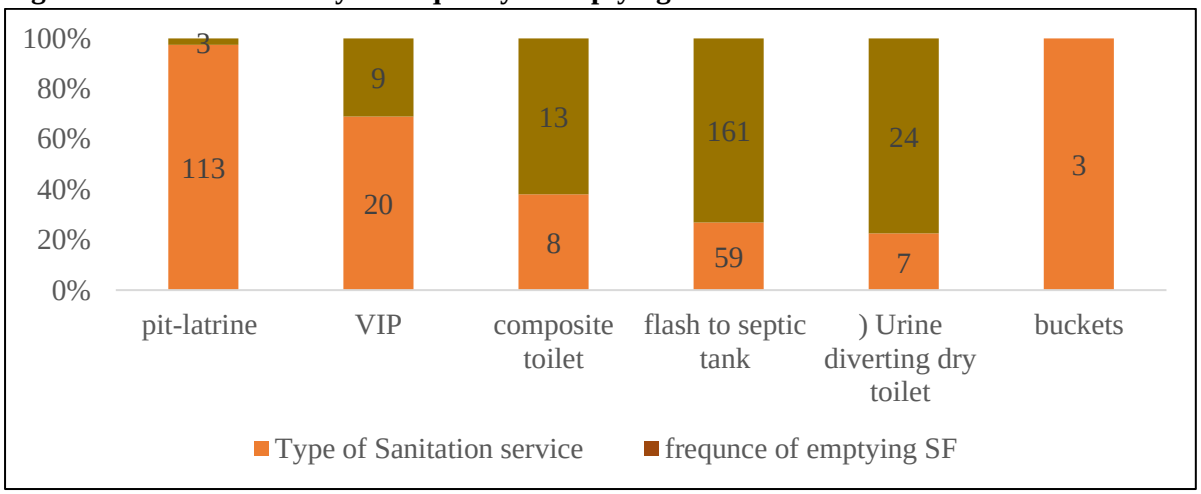


Source: (Filed data 2023)

Type of Sanitation Facilities and Duration of Residence

The analysis of sanitation facilities used reveals insights into the community's infrastructure and resilience to flooding, highlighting varying vulnerabilities among different types. Residence duration plays a crucial role in understanding historical flood exposure and adaptive capacity, with longer stays suggesting enhanced familiarity with local conditions and increased preparedness for floods. By examining these demographics, the research gains a deeper understanding of sanitation service diversity and the community's experiences, thus improving comprehension of flood impacts on onsite sanitation in the Kanyama Compound.

Figure 5: Sanitation facility & frequency of emptying



Source: (Filed data 2023)

Challenges of Using Onsite SF

Regarding access to sanitation facilities, 117 respondents reported challenges, while 93 indicated no issues (see *Table 2*). Moreover, Figure 7's pie chart reveals that 72% of respondents observed increased floods in Kanyama, with only 28% reporting the opposite.

Table 2: Challenges of using onsite SF.

Q3	Frequency	Percent	Cumulative frequency
0	93	44.29	44.29
1	117	55.71	100.00
Total	210	100.00	

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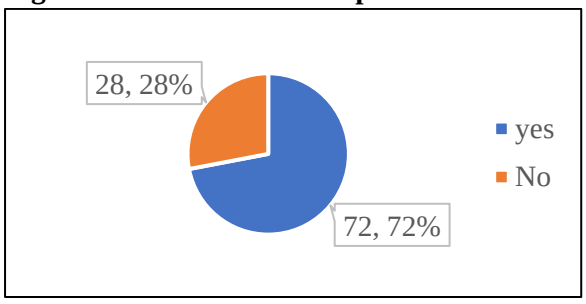
Figure 6: Increased flood experiences



Source: (Filed data 2023)

The visual narrative captured through the pictures below vividly portrays the escalating effect of increased floods in Kanyama. The images sum up the stark reality of inundated streets, infrastructure resting in floods, and the tangible consequences on residents' daily lives. Each photograph is a distressing snapshot, revealing the prevalent challenges to onsite sanitation services.

Plate 1: Kanyama ward six

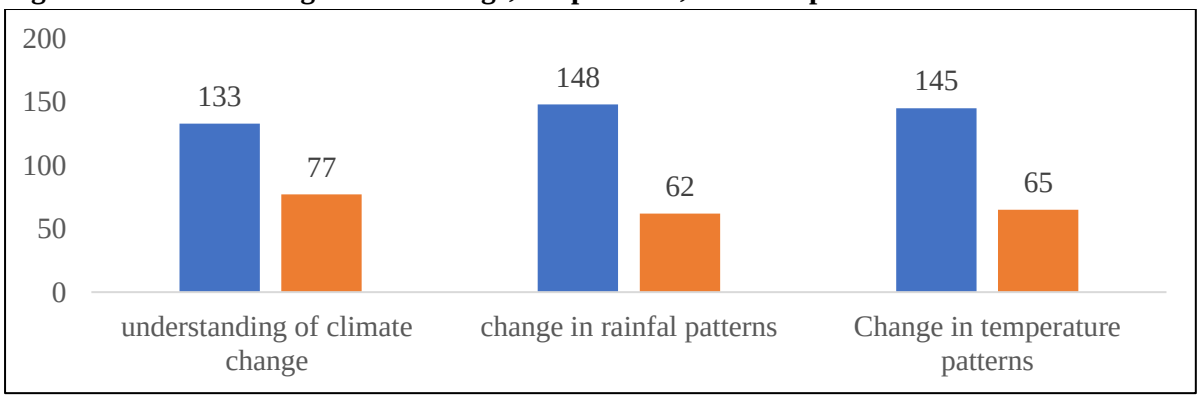
Plate 2: Kanyama ward two

Source: (Filed data 2023)

Understanding Climate Change, Temperature, And Rain Patterns Variations

Figure 8. below focuses on respondents' awareness of climate change, temperature variations, and rain pattern shifts within the Kanyama Compound. This segment delves into the community's understanding of the changing climate, providing context for their preparedness and adaptability to increased flooding. The results indicate the respondents' agreement in understanding climate change, temperature changes, and rainfall patterns.

Figure 7: Understanding climate change, temperature, and rain patterns variations



Note: the highest numbers, 133,148, and 145, indicate respondents that answered (yes), and lower numbers indicated (No) responses.

Source: (Filed data 2023)

Effects of Flooding on Onsite Sanitation Services Related to Climate Change

The questionnaire respondents in all six wards, with a mean of 0.76, indicated that the most common problem faced during the floods in the Kanyama constituency is contamination of water and infrastructure damage, with a mean of 0.67, as shown in *Table 3*. The outbreak of water and sanitation-related diseases was also considered common, with a mean of 0.68. Inundation depth,

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flood duration and area cover were parameters considered for flooding intensity and scored a mean of 0.64 and 0.65 on average; contamination of water, the blockage of roads, and overflowing of latrines and septic tanks leading human waste into water supplies were classified as more common problems during floods. This implies that severe flood effects on onsite sanitation faced by the communities have worsened due to the flooding incidences. The questionnaire respondents indicated that communities lack clean water during flood incidences due to water spreading human wastes into water supplies**.** They further revealed that the collapse of toilets is experienced, while some toilets also fill up and spill into the environment. Due to waterlogging, communities usually lose their toileting privacy. There is also an increased problem of water quality when sanitation facilities are affected. The diseases that affect communities during flooding are diarrhoeal diseases, including typhoid dysentery, especially in children, cholera, malaria, and bilharzia.

The standard deviations helped highlight the diversity or spread of responses within each category, providing a measure of how much individual data points deviate from the mean. Higher standard deviations indicated greater variability, while lower standard deviations suggested more consistency in responses across the different wards. *Table 4* shows the rotated PCA of major flooding factors in the Kanyama constituency. The PCA result extracted three factors based on the respondents' responses. To check the appropriateness of the data on the effects of floods on Onsite Sanitation in Kanyama, both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity as used by Genschick, (2018) were employed. The value of the KMO test was 0.81, signifying that the acceptability of input variables for the PCA was suitable. However, the test of the negative theory that the correlation matrix was an identity matrix reported a p-value < 0.000, showing a connection between the variables.

Consequently, PCA was, for that reason, a suitable technique for extracting flooding effects factors. Table 2 shows the retained principal component (PC) representing the different dimensions of the effects of flood incidences in Kanyama. Only variables with factor loadings of ±0.3 and above at 1% overlapping variance were used to name the factors and were significant at a 1% probability level. The three retained variables were then renamed as outbreak and contamination of water, flooding and Infrastructure damage, flooding, and overflowing of pit latrines/septic tanks. The variables were then used as the outcome variables in regression (SUR) model.

In estimating factors of floods on Onsite Sanitations in the Kanyama constituency, a seemingly unrelated regression was employed, and the results are presented in *Table 5*.

The suitability of approximating the three equations and then estimating each of the equations individually using SUR is obtained by the non-zero cross-correlation coefficients of the estimated equations' error terms. The results of the SUR model revealed that different factors affected the onsite sanitation in Kanyama. The theorized and verified independent variables were incorporated into the model, as indicated in *Table 3.* As extracted by PCA, the three retained factors of flood's effect on Onsite sanitation had variants of negative and positive coefficients. Level of education had a negative and statistically significant effect on the three variables representing the effects of floods on the onsite sanitation facilities. The coefficient of the Type of Sanitation Facility generated a negative value across all variables and is statistically essential in determining whether there can be a 'flood area cover and contamination of water and outbreak of diseases', flooding depth and Infrastructure damage, and 'flood rains and overflowing of pit-latrines/septic tanks. The family size and the other two variables are also statistically significant, with a positive coefficient in outbreaks and water contamination. The household income coefficient is negative on all three variables with a higher negative correlation of ' -0.616' on the flooding and infrastructure damage.

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As indicated in *Table 4*, the accuracy of our predictive models was evaluated using Root Mean Square Error (RMSE), with values of 1.400, 1.530, and 1.340 for the variables under consideration. In the analysis, a lower RMSE value of 1.340 indicated a higher accuracy of the predictive models. Additionally, R-squared values of 0.431, 0.427, and 0.373 for contamination of water, infrastructure damage, and overflowing of pit-latrines/septic tanks, respectively, reflected the percentage of variation in these outcomes explained by flood area cover, inundation depth, and flood rains. The R-squared values signified a superior fit of the models to the data, indicating a significant relationship between flood-related variables and the observed outcomes. Furthermore, the chi-squared statistics values of 234.16, 214.564, and 152.132 were obtained for contamination of water, infrastructure damage, and overflowing of pit latrines/septic tanks, respectively. These higher chi2 values suggested a substantial discrepancy between observed and expected data, highlighting the significant effects of flood-related variables on the outcomes studied.

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Table 3: flooding effects experienced in Kanyama.

Name of wards		Inundation Depth	Flood duration and area cover	Contamination of household items	Infrastructure damage.	Outbreak of water and hygiene-related diseases	Surface Water quality	Overflowing of pit-latrines/septic tanks
1	Mean	0.14	0.51	0.27	0.46	0.52	0.26	0.15
	SD	0.342	0.321	0.431	0.504	0.505	0.444	0.363
2	Mean	0.45	0.57	0.48	0.97	0.93	0.87	0.51
	SD	0.248	0.291	0.323	0.17	0.263	0.341	0.503
3	Mean	0.32	0.61	0.19	0.58	0.58	0.43	0.53
	SD	0.392	0.231	0.212	0.499	0.499	0.505	0.505
4	Mean	0.56	0.63	0.51	0.54	0.12	0.15	0.44
	SD	0.214	0.145	0.492	0.502	0.326	0.363	0.501
5	Mean	0.65	0.34	0.17	0.37	0.64	0.52	0.27
	SD	0.233	0.342	0.132	0.321	0.413	0.142	0.152
6	Mean	0.76	0.55	0.51	0.47	0.18	0.71	0.64
	SD	0.123	0.423	0.312	0.213	0.354	0.321	0.371
Totals	Mean	0.64	0.65	0.61	0.67	0.68	0.76	0.62
	SD	0.302	0.405	0.512	0.356	0.506	0.023	0.013

Table 4: Dimensions of effects of flooding on Onsite Sanitations-Principal component analysis (PCA)

Variables	Flood area cover/duration and contamination of water	Inundation depth and Infrastructure damage	Flood rains and overflowing of pit-latrines/septic tanks
Flood area cover and contamination of water	0.423	0.213	0.271
overflowing of pit-latrines/septic tanks	0.034	0.451	0.392
Outbreak of water and hygiene related diseases	0.432	0.433	0.371
Flood duration and area cover	0.064	0.123	0.072
Inundation Depth /rainfall	0.456	0.232	0.654
Contamination of household items	0.045	-0.153	0.032
Surface Water quality	-0.034	-0.243	-0.472
Eigenvalue	4	3	3.4
%variance	97		
correlation matrix	0.215		
KMO Test	0.92		
Barllet's test (p-value)	0.0000$^{\alpha}$		
Chi-Square	973.753		

*Note(s): **a** represents significance level at 1%.*

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Table 5: A seemingly unrelated regression model of effects of flooding on Onsite Sanitation in Kanyama constituency.

Variables	Flood area cover and contamination of water & outbreak of diseases			Inundation depth and Infrastructure damage			Flood rains and overflowing of pit-latrines/septic tanks		
	Coeff	**Std. Err**	**p>z**	**Coeff**	**std. Err**	**p>z**	**coeff**	**std. Err**	**p>z**
Family Size	0.21	0.063	0.046	0.421	0.046	0.000***	0.076	0.124	0.000***
Level of education	-0.26	0.063	0.041**	-0.192	0.145	0.032	-0.274	0.134	0.034
Duration of Residence	-0.41	0.008**	0.032**	0.0124	0.005	0.674	-0.234	0.312	0.752
Outbreak of water and hygiene related diseases	0.451	0.21	0.00***	0.345	0.034	0.032*	0.378	0.021	0.049*
Marital Status	0.07	0.31	0.671	0.026	0.340	0.56	0.112	0.153	0.712
Type of Sanitation Facility	-0.46	0.078	0.000***	-0.432	0.085	0.005*	-0.457	0.148	0.004**
Gender	-0.12	0.238	0.561	0.064	0.012	0.874	0.323	0.078	0.987
Household Income	-0.36	0.252	0.000	-0.616	0.002	0.001	-0.432	0.152	0.000***
Equation	RMSE	R-squared	chi2	p>chi2					
Flood area cover/duration and contamination of water and outbreak of diseases	1.400	0.431	234.16	0.000					
Inundation depth and Infrastructure damage.	1.530	0.427	214.564	0.001					
Flood rains and overflowing of pit-latrines/septic tanks	1.340	0.373	152.132	0.000					

*Note(s): * Significant, ** Very Significant, *** Highly Significant*

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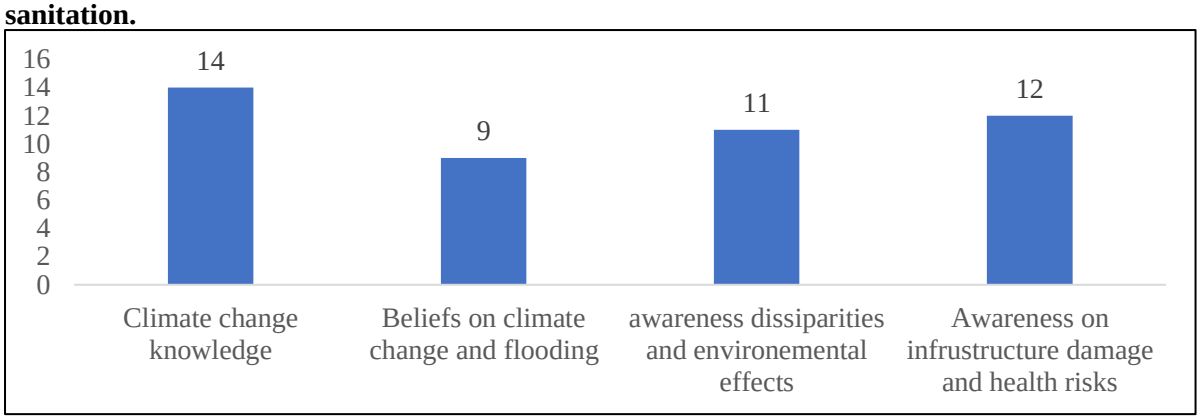
Knowledge and Awareness of the Effects of Flooding on Onsite Sanitation Services

In exploring the knowledge and awareness of the residents in the Kanyama compound regarding the effects of flooding on onsite sanitation services related to climate change, several key themes emerged.

Figure 8: themes emerged on awareness and knowledge of the effects of flooding on onsite sanitation.



(**Source**. Field data 2023)

Firstly, residents have a broad understanding of the effects of climate change on weather patterns, including intensified rains and unpredictable weather shifts, which directly affect onsite sanitation facilities such as septic's, latrines, and damages roads rendering emptying services difficult. A respondent confessed,

> *"It's been noticed that there has been increased rains in the past seasons and extreme temperatures, making poorly constructed Onsite sanitations, vulnerable to climate-related events like floods."*

The second theme is 'diverse beliefs on climate change and floodings'. The community holds diverse beliefs regarding the causes of climate change and flooding events, with some attributing them to human-induced activities like heavy urbanization and increase in population, while others view them as part of natural climate variability. Additionally, a theme on 'community awareness disparities', there are disparities in community awareness, with some individuals lacking knowledge about the link between climate change, flooding, and sanitation, but many of the respondents actively portrayed knowledge of the effects of floods on Onsite sanitation services. One respondent said,

> *"I often attribute these occurrences to climate change as I witness firsthand the erosion, loss of infrastructure, and displacement of people due to flooding, reinforcing their belief in climate change impacts."*

Awareness of infrastructure damage and health risks. On this theme, residents acutely showed awareness of the structural damages and health risks inflicting sanitation facilities, the contamination risks in groundwater and surface water, and the increased health risks, especially waterborne diseases, during and after floods, which are the direct consequences of climatic variations. A respondent indicated,

> *"We have witnessed, Debris carried by floodwaters, such as plastics, leaves, and other materials, can clog pipes and drainage systems connected to onsite sanitation facilities. This can impede the flow of waste, leading to blockages and malfunctioning toilets."*

Another respondent voiced,

> *"Here in Kanyama several People know that Floodwaters contaminates groundwater sources, including wells and aquifers. If pit latrines or septic tanks are damaged, human waste and pathogens can seep into the*

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groundwater, posing a significant risk to community water supplies."

Another respondent confessed,

"Yes, people know and have experienced that Floodwaters can overflow and mix with sewage, creating a mix of human faeces and water, causing air pollution, and waterborne diseases like cholera, typhoid, and dysentery."

Lastly, the emerging theme was 'lack of tailored education on climate change'. There is a need for tailored and community-driven approaches to address awareness disparities about climatic variations and floods' effects on onsite sanitation services. By incorporating local languages, culture, and active community involvement, these strategies aim to bridge the knowledge gap, enhance awareness, and empower the community to effectively tackle the challenges posed by climate change-induced flooding in the context of onsite sanitation services. The emphasis on continuous evaluation through feedback mechanisms further highlights the commitment to the ongoing improvement and relevance of these educational initiatives. A respondent said,

"There is a need for a targeted educational program addressing specific misconceptions and use of community-friendly language like Nyanja or bemba and interactive methods to engage residents effectively. Ensure that educational materials and workshops are conducted in the local language and are culturally sensitive. Relate climate change and onsite sanitation issues to traditions, and everyday experiences for better understanding."

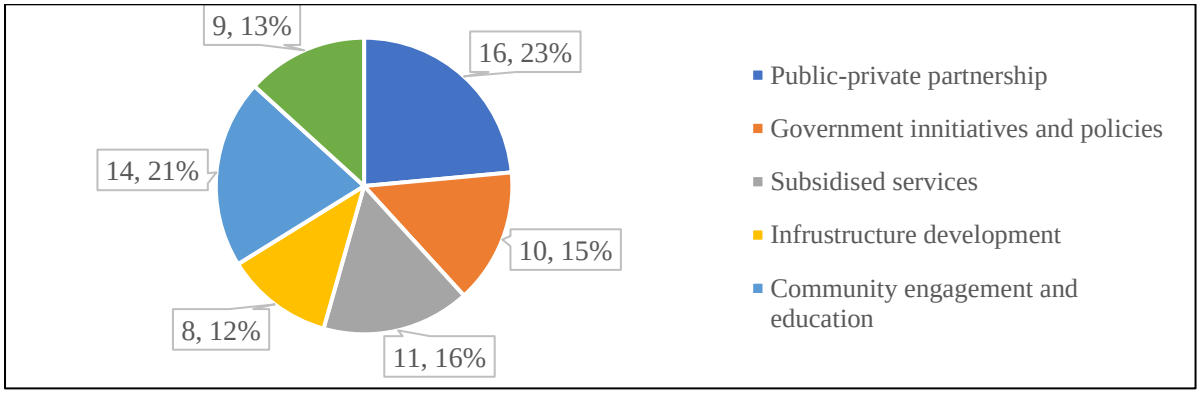
One key informant indicated also,

"There is a need to Establish a feedback mechanism to continuously assess the effectiveness of educational initiatives. Regular surveys and community meetings can help gauge the effect of awareness programs and identify areas that still need attention."

The strategies put in place by the community, government, and stakeholders to address the challenges of onsite sanitation service delivery.

The identified themes for strategies are Public-Private Partnerships, Infrastructure Development, Government Initiatives and Policies, Community Engagement and Education, and Subsidized Services, as indicated in *Figure 9* below**.**

Figure 9: Themes emerged under strategies



Source: (Field data)

The researcher discovered that collaborations exist between public institutions (such as the Lusaka City Council and Lusaka Water and Sewerage Company) and other private operators in building sealed septic tanks. LWSC has partnered with private businesses to provide pit emptying services and treatment sites in two peri-urban areas. Efforts to improve sanitation infrastructure, including constructing sewer lines, drainage systems, and VIP toilets, are in place. These initiatives aim to provide access to proper sanitation services in peri-urban, Kanyama

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inclusive. The Zambian government has put more effort into enhancing sanitation service delivery by implementing a national sanitation policy and planning framework. As indicated by the key informant from the Lusaka City Council,

> *"The Zambian government launched a new national sanitation policy and planning framework. This framework sets out a vision for Safe, affordable, and sustainable water supply and sanitation services for all. The framework includes a number of strategies to improve onsite sanitation service delivery; Strengthening the regulatory framework for onsite sanitation services; Promoting public-private partnerships, raising awareness of the importance of sanitation and hygiene, and subsidizing the cost of sanitation services for low-income households."*

There is also an ongoing implementation of subsidized sanitation services, where residents pay a reduced amount (20% of the total) for LWSC blue toilets. This approach aims to make sanitation services more affordable for low-income households. A key informant said,

> *"We are also building VIP toilets at a subsidized amount, where residents only pay 20% of the total amount."*

Community mobilization and education exist to promote proper sanitation and hygiene practices by Plan International Zambia, a non-state actor. These promote WASH services in Kanyama and help drive behavioural change related to sanitation among the residents.

> *"As Plan International Zambia, we provide Water, Sanitation, Hygiene (WASH) services in Kanyama compound to improve the overall well-being and health of the community. Our initiatives focus on implementing sustainable sanitation solutions, promoting hygiene practices, and ensuring access to clean water, clean toilets, effective waste management, designated hand washing stations, empowering residents to lead a healthier life and fostering a cleaner, safer environment for everyone."*

The final theme under this objective is health risk prevention. Diseases like cholera, typhoid, and dysentery become rampant during floods due to poor sanitation. Because of this, the government is improving the sewer systems to handle heavy rainfall and prevent the contamination of water sources during floods. This will ensure that sewage is safely transported away from residential areas and significantly reduce the risk of waterborne diseases. Lusaka city council, through private contractors, offers Flood-Resilient Toilet Designs. This is to curb spillage of faecal matter during floods. An informant from Lusaka city council said,

> *"When residents want to erect a toilet, they come, and we offer them advice on how and where to build the toilet where we factor in climatic mitigative measures."*

The researcher also identified unconventional sanitation methods, notably "flying toilets" and buckets, emerging as a coping mechanism in the Kanyama Compound. Residents resorted to innovative yet makeshift solutions except during floods and in the absence of functional and flood-resistant sanitation infrastructure. Unfortunately, "Flying toilets" involved the disposal of human waste in plastic bags into flooded waters, while the use of buckets provided a portable waste disposal option in unsafe open areas when floods compromise conventional systems. Despite offering immediate relief, these strategies pose environmental and health risks due to indiscriminate waste disposal. Respondents confessed,

> *"Since there are poor and inadequate toilets, people use plastics and buckets to help themselves, but they just throw in dumpy waters and open spaces."*

By implementing these strategies, communities can enhance their resilience against waterborne diseases during floods, ultimately contributing to effective health risk prevention in the context of onsite sanitation.

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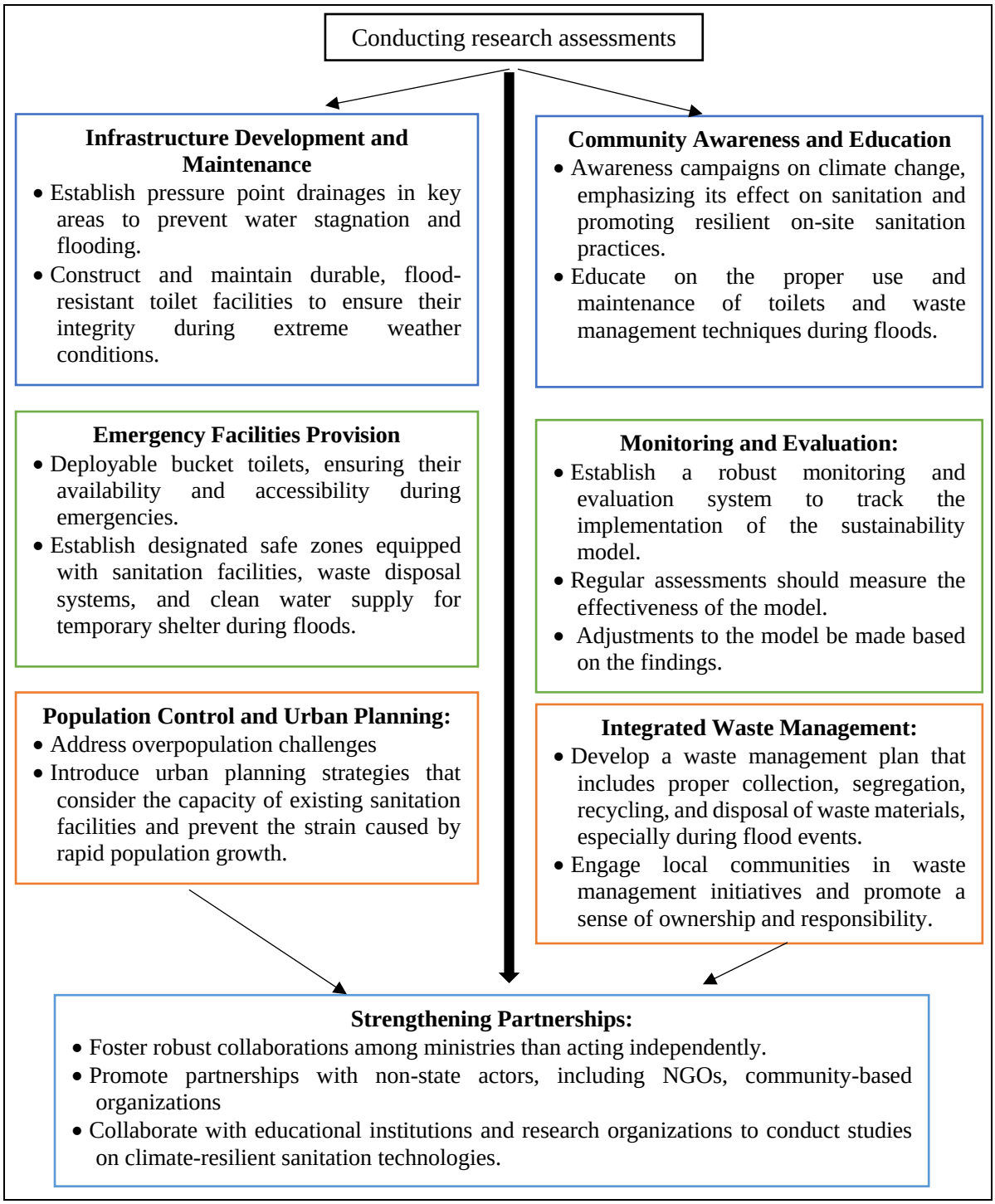
Figure 1: Sustainability model aimed at improving onsite sanitation.



Developing a Recommendation

Due to the effects of flooding on onsite sanitation, awareness levels, strategies and literature reviews on the existing models, the researcher developed a comprehensive sustainability model aimed at improving onsite sanitation service delivery in Kanyama, considering challenges such as lack of pressure point drainages, insufficient awareness campaigns on climate change, absence of bucket toilets during flooding, inadequate waste management, roads, drainages, and landscaping, lack of essential infrastructures, overpopulation, poor toilet construction integrity, limited partnerships with non-state actor, and minimal

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monitoring and evaluations on the laid out programs.

DISCUSSION

Demographic Characteristics and Flood-Related Effects on Onsite Sanitation

Research indicates that higher levels of education within households correlate with reduced impacts of flood incidents on onsite sanitation, including lower risks of water contamination, disease outbreaks, infrastructure damage, and overflow of pit latrines or septic tanks. This suggests educated household heads are better informed about managing flood effects on sanitation. Improved sanitation facilities also significantly mitigate flood impacts, aligning with the Maputo sanitation trial findings that enhanced facilities prevent faecal contamination (Holcomb et al., 2020). Conversely, increased household income negatively affects flood impacts on sanitation, suggesting financial resources bolster resilience against such crises. However, larger family sizes exacerbate flooding issues due to increased faecal exposure risks, highlighting the need for effective, locally supported sanitation solutions. According to Conaway et al. (2023), cost factors influence emptying practices of onsite sanitation systems, with mixed findings on the impact of economic status on these practices, suggesting a complex interplay between affordability, preference for emptying methods, and demographic characteristics in addressing flood-related sanitation challenges.

Awareness And Climate-Induced Floods' Effects on Onsite Sanitation

This study revealed a significant awareness among Kanyama residents about the impacts of climate change-induced floods on onsite sanitation, with a particular emphasis on climate change knowledge as the most recognized theme. This understanding is crucial for risk management and aligns with previous findings that link vulnerability to floods with a lack of environmental awareness (Glaus et al., 2020). Despite high knowledge regarding infrastructure damage and health risks from floods, persistent sanitation challenges suggest that awareness alone may not suffice to drive behavioural change. The study also identifies disparities in awareness levels attributed to differences in education, media exposure, cultural practices, and resource availability, highlighting the need for targeted interventions to bridge these gaps. Furthermore, cultural beliefs hindered improvements in onsite sanitation against flood impacts, indicating the necessity for education and awareness campaigns tailored to local contexts. The research underscores the importance of diverse information sources, including formal education and digital platforms, in enhancing understanding and preparedness for flood-related sanitation challenges.

Strategies In Place to Address the Effects of Flooding

This research has illuminated various strategies and policies implemented by both governmental and non-state actors to mitigate the effects of flooding on onsite sanitation services. Concerning infrastructure development, the researcher found that the government was addressing sewer pipe issues with assistance from some private organizations. However, challenges persisted for some residents in being reached by service providers due to the area's shanty and densely populated nature. Additionally, some lacked the necessary resources to upgrade their onsite sanitation facilities to make them flood-resistant. These findings align with the research of Singh et al. (2017), which emphasizes the importance of implementing and enforcing building and health codes to standardize the construction of onsite sanitation systems (OSSs). The prevalence of poorly constructed OSSs can be addressed through such measures. Furthermore, low-income housing often fails to meet building requirements due to its limited space and high population density (Chiliboyi., 2016). Below are government plans and policies to improve onsite sanitation in Kanyama.

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Visions and Plans

The Zambia Vision 2030 sets ambitious targets to secure access to safe potable water and improved sanitation facilities for all Zambians by 2030, aiming for 90 per cent sanitation access (O'NEILL, M. I. A. (2009). This vision is dedicated to enhancing environmentally friendly sanitation in urban and rural settings, including informal settlements, through the reconstruction and rehabilitation of sewerage treatment infrastructure. The Eighth National Development Plan (8NDP) for 2022-2026 further supports this vision by addressing sanitation infrastructure inadequacies and promoting sustainable solutions. However, the plan's focus on conventional sewerage systems and the lack of mention of new household-level policies and regulations reveal critical areas that require attention, such as the need for decentralized services, sustainable financing mechanisms, and improved inter-ministerial collaboration.

Policy and Regulatory Framework

The National Water Supply and Sanitation Policy of 2020 underpins Zambia's efforts towards achieving universal access to clean water and adequate sanitation, aligning with the Vision 2030 and Sustainable Development Goals (SDGs). It outlines objectives to develop and operate water supply and sanitation infrastructure, emphasizing preventive maintenance, appropriate technology, public health, environmental sustainability, and the integration of cross-cutting issues such as gender and social inclusion. This framework is pivotal in creating an enabling environment for sustainable water and sanitation services provision.

Subsidized Toilets

The implementation of subsidized sanitation services, exemplified by the reduced-cost LWSC blue toilets, represents a practical approach to improving sanitation access in communities like Kanyama. This strategy, supported by scheduled emptying services from organizations like the Kanyama Water Trust, aims to reduce public health risks. The importance of adequate sanitation for community health and resilience against environmental challenges underscores the need for comprehensive awareness campaigns, stakeholder engagement, and educational initiatives to empower residents and facilitate community-driven, sustainable sanitation solutions (Zhang et al., 2023).

CONCLUSION

The persistent effects of climate change-induced flooding on onsite sanitation services in the Kanyama compound are undeniably severe and multidimensional. The rising frequency and intensity of floods exacerbate the vulnerability of existing sanitation infrastructure, leading to widespread contamination of water sources, compromised hygiene, and increased health risks for the community. The inundation of pit latrines and septic tanks during flood events poses a significant threat to the overall sanitation conditions in Kanyama, perpetuating a cycle of environmental degradation and public health challenges. Urgent and comprehensive measures are imperative to address the intricate interplay between climate change, flooding, and sanitation in this community, necessitating a combination of resilient infrastructure, community engagement, and sustainable urban planning to mitigate the adverse effects and build a more resilient and adaptive sanitation system.

Further, residents are acutely aware of the effects of climate change on poorly constructed sanitation facilities. Diverse community beliefs underscore the need for targeted education. While efforts by the community, government, and stakeholders involve strategies like Public-Private Partnerships, Infrastructure Development, and Community Engagement to enhance sanitation infrastructure and awareness. Finally, a proposed framework to help alleviate climate change-induced flooding effects on onsite sanitation in Kanyama.

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Ethical Approval

The University of Zambia Natural and Applied Sciences Ethics Committee-IRB of the Directorate of Research and Graduate Studies permitted this study. Permission to collect data from the study site was also obtained from the Board of Graduate Studies and other relevant authorities. Participants who took part in the study completed consent forms and were assured of anonymity.

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