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Water Security Characteristics of Existing Water Service Provision Systems in Informal Settlements within Nairobi County, Kenya

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ABSTRACT

Attainment of water security in urban informal settlements in developing countries can be a complex undertaking due to various factors that affect water service provision, such as insufficient water quantities, unreliable water supply, aging pipes, and infrastructure coverage, among others. In addition to this, the territorial behaviour and therefore a siloed approach of service providers propagate water insecurity. This situation has an impact on the socio-economic development, peace and political stability, water-related disasters, and waterborne diseases in many urban informal settlements in developing countries. The study sought to assess water security characteristics in informal settlements in Nairobi County. The research was informed by the systems theory. The study adopted a descriptive research design. The research targeted a population of 2,511,991 people living in the informal settlements and 544 water service providers (formal utilities and small-scale vendors) operating in the informal settlements. Both probabilistic and non-probabilistic sampling methods were used in this study to select the respondents. Data was collected from a sample of 388 households and 62 water vendors from nine slums in 12 sub-counties. A household questionnaire was used to collect data. Data was analysed using descriptive and inferential statistics. From the findings, only 0.4% of households met all six parameters (availability, access, quantity, quality, affordability, and reliability) of water security. Most of the households satisfied four parameters, 30% met three parameters, 20.8% met two parameters, 11.7% met five parameters, and 5.3% met one parameter. This pointed to a situation where water security is a major concern in Nairobi's Informal Settlements (INSEs). The existing water structures of service provision influenced only three of the six water security factors, and that is, availability, access, and quality. The level of structure did not have any impact on quantity, affordability, or reliability of water services. The study therefore concludes that the provision of infrastructure alone may not necessarily lead to overall household water security. The research findings show that integration is possible along the three levels—water production, water delivery infrastructure, and service levels experienced by the households. It was however noticed that a household could depend on multiple sources and therefore experience various levels of services. The study recommends that the national and county governments and stakeholders in the water sector, while planning water service provision and infrastructure development, should ensure that efforts towards attaining universal access to water through availability, access, quantity, quality, affordability, and reliability should have a targeted approach to reach those who are most water insecure.

Keywords: Formal Water Service Provider, Informal Settlements, Informal Water Service Provider, Water Security, Water Service Provision System

I. INTRODUCTION

Urban informal settlements in developing countries are faced with water insecurity issues, which can be traced to insufficient water quantities, unreliable water supply, aging pipes, infrastructure coverage among others (Hanna-Attisha et al., 2016; Majuru, 2015; United Nations Development Programme [UNDP], 2011; Van der Bruggen et al., 2010). It is considered that, water insecurity has a direct correlation to socio-economic development, peace and political stability, water related disasters and waterborne diseases (UN Water, 2013). In order to mitigate this, countries experiencing insufficient water quantities have instituted measures like extension of distribution network, increasing production and storage capacity (Dziegielewski, 2003). The realisation of this is dependent on robust production and distribution strategies which sometimes is a challenge in most of the developing countries (Leigh & Lee, 2019). On the other hand, development of alternative supply channels including drilling of boreholes and allowing for tank truck distribution have been used to address unreliable water-supply (Bartram & Cairncross, 2010; Griffin & Mjelde, 2000). Further, many developing countries are struggling with infrastructure development leading to under-coverage in low-income areas (LIAs) like in urban informal settlements. This has led to low water pressures in the water distribution system and due to aging pipes, huge water losses are experienced, hence high unaccounted for water (UfW) (Lai et al., 2020). Leigh and Lee (2019) note that the main cause of these challenges in developing countries include non-adherence to formulated standards and uncoordinated water-supply systems. Further, there seem to be lack of proper plans to exploring local alternative water sources to supplement the existing water quantities (Sapkota et al., 2014; Marlow et al, 2013).

Moreover, a well-coordinated water-supply system that reflects on the context in terms of flexibility and adaptability in which it has been designed, has been considered to be key in addressing water insecurity (Ahlers et al. 2014; Hammer et al. 2011). However, it requires those with the responsibility of water service provision to explore diverse and flexible solutions (Brown et al., 2011; Keith & Brown, 2009). Some of the ways to achieve this involved a system-wide collaboration among entities involved in the water provision. The UN Water (2015) notes that players involved in the water service provision tend to operate in silos. Whereas the ultimate goal is to ensure water security, the challenge of working in a collaborative manner is still a bottleneck. The application of system dynamics principles has been touted to be a possible way of tackling this (Sušnik et al., 2013; Abdi, 2009; Saysel, 2007). Water security has been described to constitute availability, access to adequate quantity, quality, affordable and that is reliable (UN Water, 2013). Through these attributes, it is anticipated that people sustain access and livelihood, ensure human well-being, lead to socio-economic development and protection from water-borne pollution. In essence this leads to reduction in water-related disasters and preservation of ecosystems in a climate of peace and political stability. For instance, the quantity of water accessed by a household has been a topic of interest since it affects human health.

According to Stelmach and Clasen (2015), different amounts of water are required to sustain human health. The SPHERE Project (2004) sets out 15 litres per capita per day (15 lpcd) per person as a minimum standard for sustaining human life. Also, the World Health Organisation (WHO) cites a minimum for basic health protection of at least 20 lpcd, of which 7.5 litres is required for consumption, including direct hydration, survival, hygiene practices and cooking (WHO, 2011). Recently, House et al., (2017), added that, the minimum quantity of drinking-water needed for survival is three to five litres per person per day depending on the temperature, and an individual’s level of exercise. They postulate that quantities of water used per capita per day fluctuates with distances that have to be walked to collect water and that this usage increases with the improved convenience of a piped supply, when a new source nearer to the home is realized, or when income levels increase. To achieve water security in informal settlements, the quantity of water to be accessed should lead to sustainable livelihood, socio-economic development of the people, reduction of water-related disasters, and foster coexistence. This calls for a well-defined water service provision system whose main players are regulated. Unfortunately, there exist some water service provision systems which are marked by informality. This therefore introduces what can be described as informal water service provision whose main players are unregulated.

1.1 Statement of the Problem

Urban informal settlements in developing countries are faced with water insecurity issues, which can be traced to insufficient water quantities, unreliable water supply, aging pipes, infrastructure coverage among others (Hanna-Attisha et al., 2016; Majuru, 2015; UNDP, 2011; Bruggen et al., 2010). Further, many developing countries are struggling with infrastructure development leading to under-coverage in low-income areas (LIAs) like in urban informal settlements. This has led to low water pressures in the water distribution system and due to aging pipes, huge water losses are experienced, hence high unaccounted for water (UfW) (Lai et al., 2020). Due to high levels of poverty of people living in these settlements, they end up sourcing water from unsafe sources leading to water borne diseases (Mollah et al., 2009; Jouravlev 2004; Black et al., 2003). In informal settlements and slums, water insecurity is seen as a critical public-health challenge (Adams et al. 2022). However, what is missing is a well-coordinated water-supply system that reflects on the context in terms of flexibility and adaptability in which it has been designed. This could be the case since the water service providers have not been able to explore diverse and flexible solutions through a system-wide collaboration among entities involved in the water service provision. It observed in Nairobi County that players involved in the water service provision tend to operate in silos or even compete (UNDP, 2011). Whereas the goal is to ensure water security, the challenge of working in a collaborative manner is still a bottleneck. This advances that if these challenges were not addressed, there is continuation of non-adherence to formulated standards and uncoordinated water-supply systems. Further, this leads to lack of proper plans to exploring local alternative water sources to supplement the existing water quantities. In essence, this situation continues to have an impact on socio-economic development, peace and political stability, water related disasters and waterborne diseases.

1.2 Research Objective

To assess the domestic water security characteristics of existing water service provision systems in informal settlements within Nairobi County.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1. Systems Theory

The research was informed by a systems theory. The major proponents of systems theory include the physician Alexander Bogdanov as studied by Gare (2000), sociologist Talcott Parsons (Parsons, 1970), study of biological systems by Ludwig von Bertalanffy (Von Bertalanffy, 1951; Wolfgang, 2005), the study of management by Peter Senge (Senge, 1990), and the study of organizational theory by Fritjof Capra in (Capra, 2022), among others. Systems thinking is a world view in which objects are seen to be interrelated with each other (Whitchurch & Constantine, 2009). The systems theory helps us to view identify elements of a system and the role they play; helps to predict how the element may impact other elements in the system either because of endogenous or exogenous conditions; and how making use of the information generated can help inform optimal decision-making hence maximizing the utility derived from the system. The study of water security in Nairobi County's INSEs involved framing the water supply system through six variables whose integration would lead to a water secure household or settlement. The variables include availability, access, quantity, quality, affordability and reliability of water services. The systems theory helped the researcher to put into perspective the importance of considering all the six factors during design of water supply systems, without which attainment of water security will continue to be an elusive effort.

2.2 Conceptual Review

The concept of water security has gained a lot of interest in academic research, policy formulation and in sustainable development agenda globally. This interest may be associated due to the concern of its potential risk that is associated with either water scarcity (for humans and/or the environment), floods or harmful water quality (Hall & Borgomeo, 2013). The level of tolerance of society to these risks is what defines water security (Grey et al., 2013). But still, there have been various arguments on what constitutes water security with some looking at basin level (Babel & Shinde, 2018) and others looking at urban level (Aboelnga et al, 2019; Babel et al., 2016). There have also been water security studies that have summed it to imply reliability, that is, a water supply system that has no chance of future shortfall with optimal investment (Griffin & Mjelde, 2000). Further, attaining water security with the consumer preference is seen to be the most preferred approach (Griffin & Mjelde, 2000), thus providing for qualitative aspects. Depending on the area of research, other aspects of water security have emerged that include issues such as environment, mitigating risks, hazards and avoiding conflict over shared waters (Wuysang et al., 2018).

Lankford et al. (2020) note that the concepts of water security are protecting the environment, working together, understanding how water is interconnected with things like making energy, meeting city needs, climate change, and food, and making sure that everyone has access to water fairly and equally. Two actions are taken to ensure environmental sustainability: the sustainable management of water as part of a green economy and the restoration of ecosystem services in river basins to enhance river health (Moumen et al., 2019). The drivers of water security are the internal and external elements that might impact both the quality and quantity of water. According to Barry and Sidel (2011), water security can be achieved when there is an ample amount of water available in a certain area and there is no threat of the water supply running out. Evans et al (2006) have categorized these drivers as having climatic, demographic, or economic characteristics. In addition, Brears (2016) identified urbanization and climate change as significant factors contributing to water security in the twenty-first century. Alaerts and Kaspersma (2009) contend that the challenges of water service provision are not just due to urbanization and climate change. They believe that the unsustainability elements and hazards associated with urban water management also have an adverse effect on the reliability of water resources.

Urban regions face a distinct challenge in ensuring water security, which is of particular concern. The specific challenges encompass heightened strain on water resources as a result of population expansion, migration, industrialization, water body pollution, and excessive extraction of groundwater (Babel et al., 2016). Conversely, it is argued that climate change and variability exacerbate the difficulties that urban water infrastructure in underdeveloped nations is already encountering (Poustie & Deletic, 2014). According to Satterthwaite (2008), it has been asserted that the majority of countries that are expected to experience significant limitations on the supply of freshwater due to climate change are nations with low and middle-income levels. Climate change has a disruptive impact on the water cycle and the process of precipitation. Scientists from the Intergovernmental Panel on Climate Change (IPCC) have stated that there is a high probability that human activities have impacted the global water cycle since 1960. The First Assessment Report of the Urban Climate Change Research Network (UCCRN), authored by Hammer et al., (2011), highlights the substantial impact of flooding and droughts on the availability and quality of water supply in numerous cities. Therefore, it is necessary for those in charge of water management to prioritize the improvement of their supply networks in order to optimize the utilization of current resources (Hammer et al., 2011).

There are several views on what constitutes water security leading to lack of unified conceptual and methodological models to address its negative impact. Accordingly, key metrics for measuring water security have emerged. Table 1 provides the description of these metrics.

Table 1
Water Security Indicators

Description	Metrics	Implications	Source
Water security should include access to safe water at affordable cost to enable healthy living and food production, while ensuring the water environment is protected and water-related disasters, such as droughts and floods, are prevented.	Access Safety Affordability	Healthy living Food production Environmental protection Prevention of disaster	Cheng et al. (2004)
Water security is focused on the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies.	Availability Quantity Quality	Healthy livelihood Ecosystem and production Acceptable risk (environment and economic)	Grey & Sadoff (2007).
Defined water security as, availability of water of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies.	Availability Quantity Quality	Risk – disaster Environment Economic	Grey & Sadoff (2007)
Water insecurity is defined as insufficient and insecure access to adequate water for a healthy lifestyle (FAO, 2004; Stevenson, Ambelu, Caruso, Tesfaye, & Freeman, 2016).	Quantity Access	Health Lifestyle	Stevenson et al. (2016)

Depending on where a study is domiciled, and the utility to be derived, the need to align the water characteristics to the scope is important. For informal settlements, the utility derived from water is that of domestic use which focuses on water used for drinking, cooking, cleaning, sanitation, and personal hygiene (Howard & Bartram, 2003). For this case, the characteristics as may appear in several definitions in, reliability, quantity, quality, and affordability are the indicators to measure. Reliability is measured in terms of length of downtime per year and if seven (7) days in 365 days, it is acceptable. Quantity is measured in terms of litres per capita per day and globally, 50 l/c/d is acceptable, but this depends on country to country. Quality has both physical-chemical and biological parameters, but taste, odour and colour may also dictate acceptability (Shaw, 2014). Affordability is measured in terms of cost per cubic meter of water but as a rule of thumb households should not spend more than 3% of their household income for water, to be considered affordable.

Water service provisioning is characterized by system that is composed of three key elements. First element is that of service providers (formal, informal); system structures (water source development, treatment, storage, and delivery) and regulation which means that the system operates within certain laws and regulations also known as governance and management structures (Hodgson, 2003). The level of investment of equipment and infrastructure put in place therefore dictates how the final user or customer accesses the water. There are water sources with minimal infrastructure and therefore access happens at or near the water source. As the systems develops to deliver water closer or to the customer through pipes, more complex structures start to emerge. These more complex systems also are accompanied with measures to manage the water without cause of conflict, and these are what form the regulatory frameworks. The latter may control who gets access and who makes decisions.

III. METHODOLOGY

The research was conducted in Nairobi County which has 17 sub counties, however the study focused on 12 sub counties which form informal settlements in the County. The research targeted a population of 308,456 people (Kenya National Bureau of Statistics [KNBS], 2019) living in the informal settlements. A sample size of 388 household heads was drawn from the 12 sub-counties selected from a total of 17 sub-counties in Nairobi County. Descriptive research design was adopted for this study. A two-stage cluster Sampling was used with distribution based on population proportional to size (PPS). Table 2 gives the sample of the households interviewed in each cluster.

Table 2

Sampling Frame for the 12 Sub-Counties

Sub County	Sub County Population	Estimated Slum Cluster Population	Proportion of Population (%)	Number of Household Heads Sampled
Dagoretti North	133,504	24,899	18.65	18
Dagoretti South	160,718	7,281	4.53	30
Embakasi	663,211	60,684	9.15	66
Kamukunji	220,659	22,882	10.37	26
Kasarani	525,624	54,507	10.37	43
Kibra	212,261	13,606	6.41	27
Lang'ata	178,282	8,790	4.93	9
Makadara	160,434	7,909	4.93	15
Mathare	193,416	9,535	4.93	19
Ruaraka	283,449	42,404	14.96	89
Starehe	159,709	37,723	23.62	18
Westlands	247,102	18,236	7.38	28
Totals	**3,138,365**	**308,456**	**100**	**388**

The study used questionnaires as the main research instruments. The data collected were analyzed using both descriptive and inferential statistics. The descriptive statistics includes frequency, percentage, and mean scores while the inferential statistics was mainly chi-square test and findings presented in form of figures and tables.

IV. FINDINGS & DISCUSSIONS

4.1 Demographic Characteristics of the Respondents

Table 3 shows the demographic characteristics of the respondents involved in this study.

Table 3

Demographic Characteristics of the Respondents

Variable		Frequency	Percentage
Sex of the respondent	Female	275	71.0%
	Male	113	29.0%
Relationship of the respondent to the Household Head	Self	18	4.7%
	Spouse	4	1.0%
	Child (with permission of Parent/Guardian)	13	3.4%
	Relative	199	52.0%
	Others	149	38.9%
Age of the respondent	18 - 35 Years.	196	50.5%
	36 - 64 Years.	183	47.2%
	Above 65 Years.	9	2.3%
Highest level of education	No Education	10	2.6%
	Primary incomplete	6	1.5%
	Primary complete	88	22.7%
	Secondary incomplete	31	8.0%
	Secondary complete	131	33.8%
	Tertiary (Certificate/Diploma)	59	15.2%
	University	48	12.4%
	Postgraduate	15	3.9%
Employment Status	Not employed	99	25.5%
	Employed salaried	53	13.7%
	Employed casual laborer	82	21.1%
	Self employed	152	39.2%
	Student	2	0.5%
Monthly income	Less than 23,670	342	88.1%
	Between 23671 to 112,929	46	11.9%
Main Source of income	Aid/Cash transfer	2	0.5%
	Formal employment	47	12.1%
	Remittance from relatives	15	3.9%
	Small scale trade	199	51.3%
	Wage earner	125	32.2%

Length of stay in the current location	≤ 3 months	12	3.4%
	≥ 3 to ≤ 6 Months	21	5.5%
	> 6 to ≤ 12 Months	12	3.4%
	>1 to ≤ 2 Years	33	8.1%
	>2 Years	310	79.7%
Where you came from	Another INSE	95	24.5%
	From an urban area other than Nairobi	159	41.0%
	From a rural area	61	15.7%
	I was born here	63	16.2%
	Other, please specify:	10	2.6%
Total Number of respondents		**388**	**100.0%**

4.2 Water Availability in Sub-Counties

The study sought to determine the water availability per sub-county within Nairobi County. As the results in Table 4 indicate, the analysis showed that there was no Sub-County with universal water availability. Household water availability ranged between 10.5% being the lowest (Mathare Sub-County) and highest was 68.7% (Makadara sub-county). Further, from the Chi-Square analysis ($\chi^2_{12,0.05}$=59.784, $p<0.05$) showed that there was a strong association between Sub-County setting and the water availability. Additionally, Mathare sub-county was the leading with water not readily available as indicated by 17 (89.5%) respondents while Makadara sub-county had the least with water not readily available as indicated by 5 (31.3%) respondents.

Table 4

Water Availability versus Sub-County

		Not Readily available		**Readily available**		**Total**	
		F	**%**	**F**	**%**	**F**	**%**
Sub-County	Dagoretti North	12	66.7	6	33.3	18	100.0
	Dagoretti South	13	41.9	18	58.1	31	100.0
	Embakasi South	28	41.7	39	58.3	67	100.0
	Kamukunji	22	80.8	5	19.2	27	100.0
	Kasarani	17	40.0	26	60.0	43	100.0
	Kibra	10	37.0	17	63.0	27	100.0
	Langata	8	80.0	2	20.0	10	100.0
	Makadara	5	31.3	10	68.7	15	100.0
	Mathare	17	89.5	2	10.5	19	100.0
	Ruaraka	62	73.1	22	26.1	84	100.0
	Starehe	6	31.6	13	68.4	19	100.0
	Westlands	10	35.5	18	64.5	28	100.0
	Total	**210**	**53.4**	**178**	**46.6%**	**388**	**100.0**

Chi-Square Tests

	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	59.784[a]	22	.001
Likelihood Ratio	46.794	22	.002
Linear-by-Linear Association	11.474	1	.001
N of Valid Cases	388		

4.3 Water Accessibility

This is the proximity of water source or water point to the household measured in time or distance. This is a measure of the convenience for a household measured in terms of distance to and from the water source and/or time taken for a round-trip including queueing at the water source. The study sought to determine the overall water access among respondents in Nairobi County. From the findings, it was observed that 262 (67.5%) of them, the distance of the water source from the house was less than 100m while 113 (29.1%), the distance was between 100-200m. However, only 13 (3.4%) were moving a distance of more than 200m from their houses to the nearest water source (Figure 1).

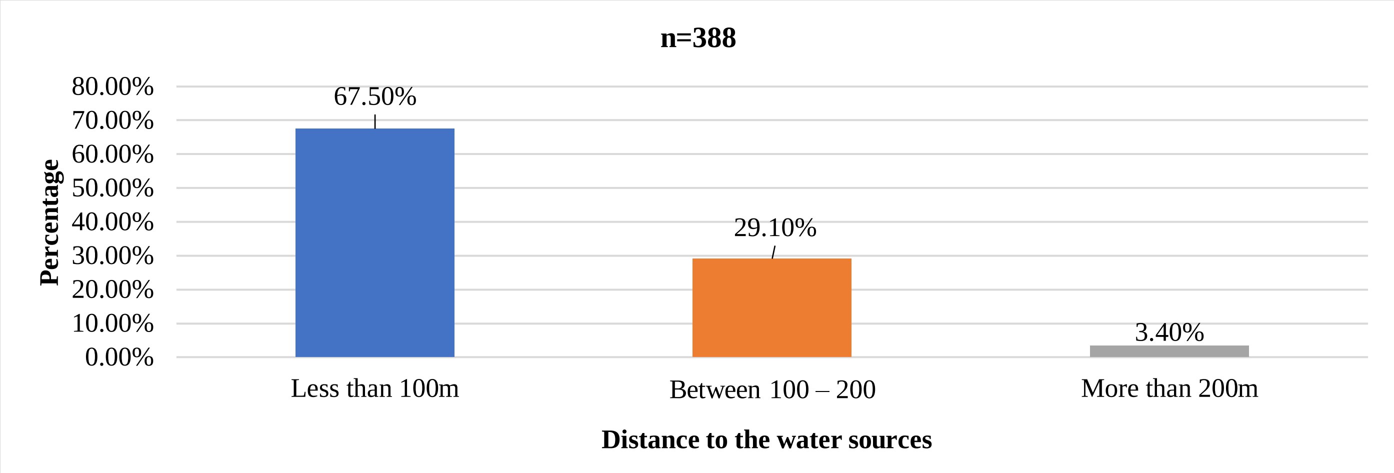

Figure 1
Distance to Water Source

4.4 Time Taken to Water Source

To compute access, the time parameter was used. This is because in an Informal Settlements (INSE) set-up, due to the un-planned nature of settlement, distance tends to be elusive and therefore people are likely to give wrong estimates. Therefore, the study investigated the time taken by the members of the household to collect water from the source. The findings shows that 255 (65.7%) used around 1- 15 minutes to collect water. Those who spent 16-30 minutes were 81 (20.9%), those who used between less than a minute were 24 (6.3%) while 14 (3.6%) used around 31- 45 minutes. The respondents who spend between 46-60 minutes were 9 (2.4%). However, only 4 (1.0%) were using more than one hour to get to the water source (Figure 2). According to Geere and Cortobius (2017), the average time taken for urban households to get water from an off-plot water source (i.e., 'elsewhere') and return home ranged from 10 minutes to 65 minutes.

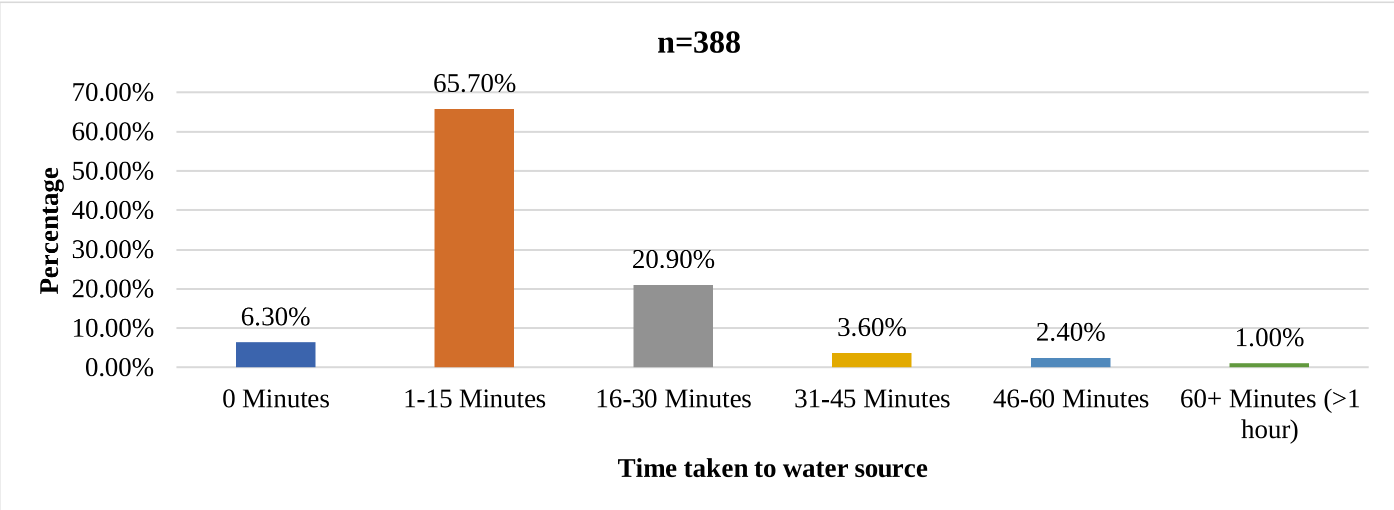

Figure 2
Time Taken to Main Water Source

4.5 Water Access in Sub-Counties

For the study to establish water security in the informal settlements, it conducted and analysis of the water access variable. From the analysis in Table 5 show, it was established that those with unacceptable water access were Dagoretti North 4 (27.8%), Dagoretti South 3 (9.7%), Embakasi South 14 (20.8%), Kamukunji 11 (46.2%), Kasarani 23 (48.0%), Kibra 9 (33.3%), Langata 2 (22.2%), Makadara 1 (6.2%), Mathare 6 (31.6%), Ruaraka 21 (23.7%), Starehe 6 (38.7%) and Westlands 10 (35.5%). On the flip coin, those with acceptable water access per sub-county included Dagoretti North 12 (72.2%), Dagoretti South 27 (90.3%), Embakasi South 54 (79.2%), Kamukunji 13 (53.8%), Kasarani 25 (52.0%), Kibra 17 (66.7%), Langata 7 (77.8%), Makadara 14 (93.8%), Mathare 12 (68.4%), Ruaraka 69 (76.3%), Starehe 10 (61.3%), and Westlands 18 (64.5%). A chi-square established that there was a significant relationship between water access and sub- county of the respondents ($\chi^2_{12, 0.05}$=28.522, P<0.05).

Table 5
Water Access versus Sub-County

		Unacceptable water access		Acceptable water access		Total	
		F	%	F	%	F	%
Sub-County	Dagoretti North	4	27.8	12	72.2	16	100.0
	Dagoretti South	3	9.7	27	90.3	30	100.0
	Embakasi South	14	20.8	54	79.2	68	100.0
	Kamukunji	11	46.2	13	53.8	24	100.0
	Kasarani	23	48.0	25	52.0	48	100.0
	Kibra	9	33.3	17	66.7	26	100.0
	Langata	2	22.2	7	77.8	9	100.0
	Makadara	1	6.2	14	93.8	15	100.0
	Mathare	6	31.6	12	68.4	18	100.0
	Ruaraka	21	23.7	69	76.3	90	100.0
	Starehe	6	38.7	10	61.3	16	100.0
	Westlands	10	35.5	18	64.5	28	100.0
	Total	**110**	**28.3**	**278**	**71.7**	**388**	**100.0**

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	28.522[a]	12	.001
Likelihood Ratio	29.623	12	.001
Linear-by-Linear Association	13.822	1	.007
N of Valid Cases	388		

4.6 National Water Quantity Standard versus Sub- County

The study did a comparison of water quantity in the various sub-counties with the national standards of water quantity as shown in Figure 3.

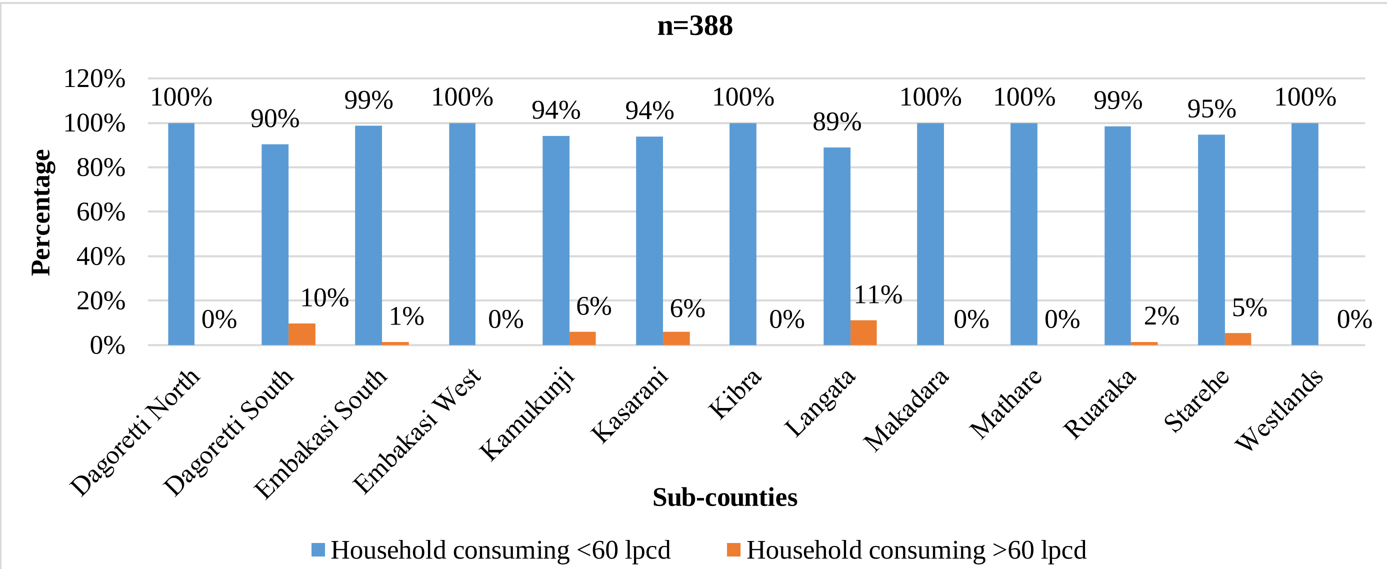

Figure 3
National Standard Water Quantity versus Sub-County

From the findings, Dagoretti North 18 (100.0%), Dagoretti South 28 (90.3%), Embakasi South 71 (98.6%), Embakasi West 1(100.0%), Kamukunji 16 (94.1%), Kasarani 46 (93.9%), Kibra 30 (100.0%), Langata 8 (88.9%), Makadara 21 (100.0%), Mathare 23 (100.0%), Ruaraka 66 (98.5%), Starehe 18 (94.7%), and Westlands 31 (100.0%) had household consuming less than 60 lpcd of water. However, Dagoretti North 0 (0.0%), Dagoretti South 3 (9.7%), Embakasi South 1 (1.4%), Embakasi West 0 (0.0%), Kamukunji 1 (5.9%), Kasarani 3 (6.1%), Kibra 0 (0.0%), Langata

1 (11.1%), Makadara 0 (0.0%), Mathare 0 (0.0%), Ruaraka 1 (1.5%), Starehe 1 (5.3%), and Westlands 0 (0.0%) were consuming water greater than or equal to 60 lpcd (Figure 3). As shown in Table 6, a chi-square of ($\chi^2_{12,\ 0.05}$=14.077, P>0.05) was established indicating that there was no significant relationship between the variables.

Table 6
Chi-Square Test of National Standard Water Quantity versus Sub-County

Chi-Square Tests			
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	14.077[a]	12	.061
Likelihood Ratio	13.066	12	.052
Linear-by-Linear Association	12.222	1	.074
N of Valid Cases	388		

4.7 Sphere Standard Quantity versus Sub-County

The study established the correlation between sphere standard quantity of water and the sub- counties in which the informal settlements are located.

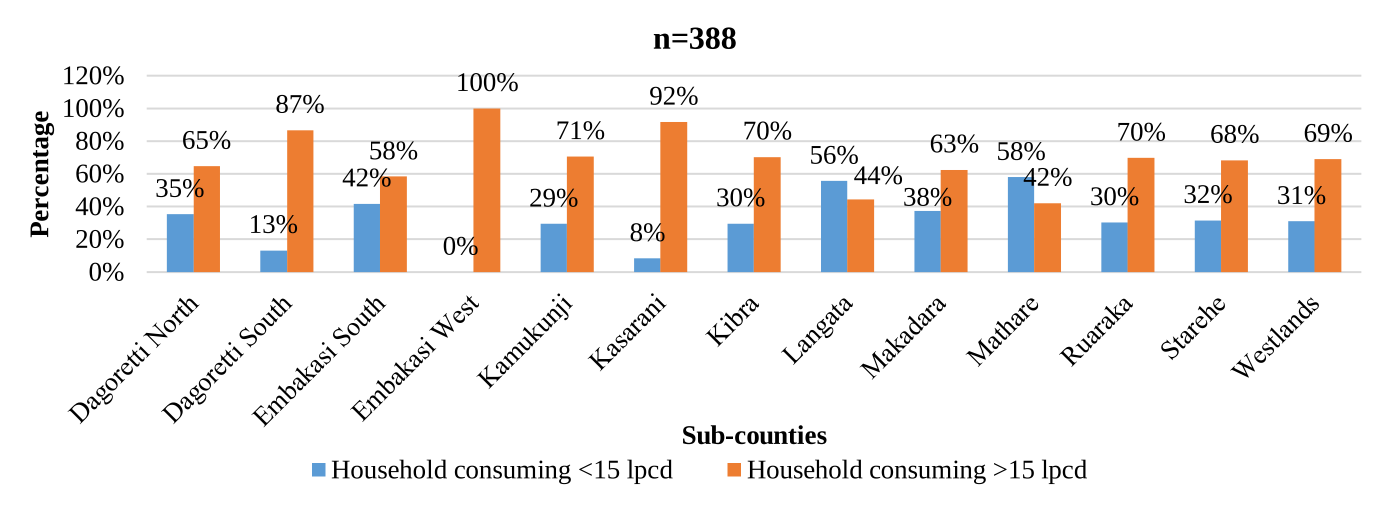

Figure 4
Sphere Standard Quantity versus Sub-County

From the findings, those households consuming greater than 15 lpcd were as follows; Dagoretti North 11 (64.7%), Dagoretti South 26 (86.7%), Embakasi South 42 (58.3%), Embakasi West 1 (100.0%), Kamukunji 12 (70.6%), Kasarani 49 (91.7%), Kibra 19 (70.4%), Langata 4 (44.4%), Makadara 10 (62.5%), Mathare 8 (42.1%), Ruaraka 50 (69.7%), Starehe 13 (68.4%), and Westlands 20 (69.0%). On the other hand, those households which consumed less than 15 lpcd were as follows; Dagoretti North 6 (35.3%), Dagoretti South 4 (13.3%), Embakasi South 30 (41.7%), Embakasi West 0 (0.0%), Kamukunji 5 (29.4%), Kasarani 9 (8.3%), Kibra 8 (29.6%), Langata 5 (55.6%), Makadara 6 (37.5%), Mathare 11 (57.9%), Ruaraka 24 (30.3%), Starehe 6 (31.6%), Westlands 9 (31.0%). Results in Table 7 show a chi-square value of ($\chi^2_{12,0.05}$=29.767, P<0.05) shows that there is a significant relationship between SPHERE Standard Quantity versus Sub-County.

Table 7
Chi-Square Analysis of *Sphere Standard Quantity versus Sub-County*

Chi-Square Tests			
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	29.767[a]	24	.000
Likelihood Ratio	25.223	24	.000
Linear-by-Linear Association	.106	1	.744
N of Valid Cases	388		

4.8 Affordability Based on Cost of 20L Container versus Sub-County

The study established the relationship between water affordability of the 20L jerry can and the various sub-counties in Nairobi County. The findings were presented in Figure 5.

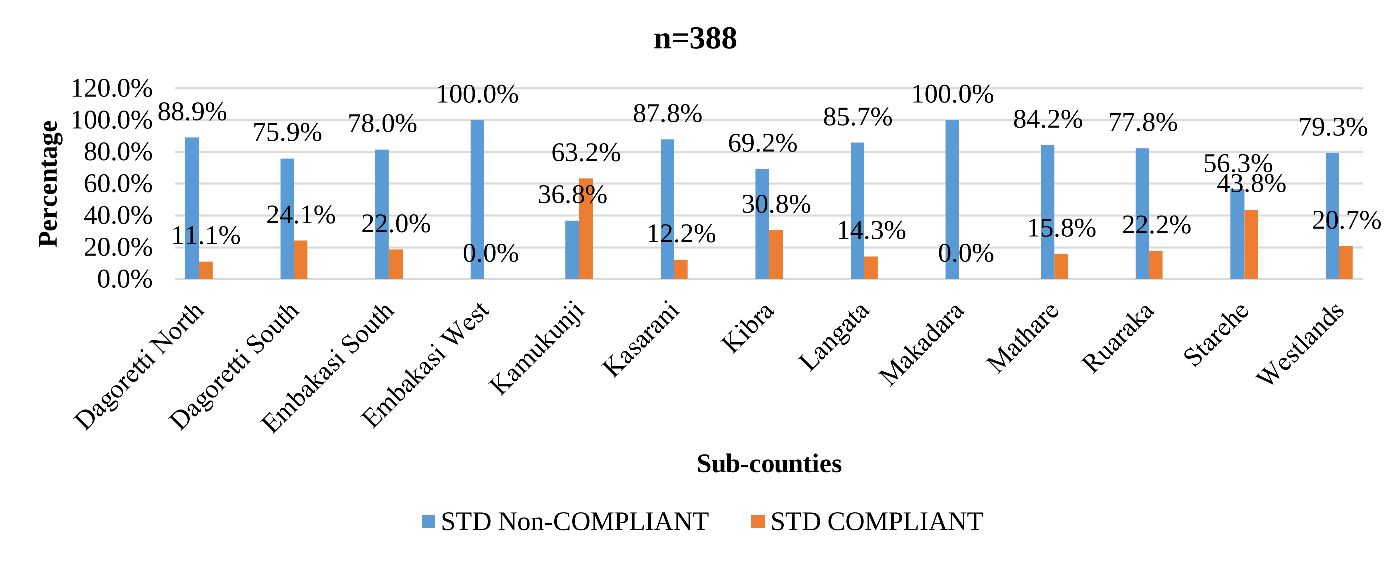

Figure 5
Affordability Based on Cost of 20L Container versus Sub-County

The results in Figure 5 show those who are standard compliant and those that are non- compliant. The statistics of the various sub-counties which are standard compliant are Dagoretti North 2 (11.1%), Dagoretti South 7 (24.1%), Embakasi South 17 (22.0%), Embakasi West 0 (0.0%), Kamukunji 12 (63.2%), Kasarani 5 (12.2%), Kibra 8 (30.8%), Langata1 (14.3%), Makadara 0 (0.0%), Mathare 3 (15.8%), Ruaraka 20 (22.2%), Starehe 7 (43.8%), and Westlands 6 (20.7%). On the other hand, those which are non- compliant in each sub-county are as follows; Dagoretti North 16 (88.9%), Dagoretti South 22 (75.9%), Embakasi South 60 (78.0%), Embakasi West 1 (100.0%), Kamukunji 7 (36.8%), Kasarani 36 (87.8%), Kibra 18 (69.2%), Langata 6 (85.7%), Makadara 16 (100.0%), Mathare 16 (84.2%), Ruaraka 70 (77.8%), Starehe 9 (56.3%), and Westlands 23 (79.3%). A chi- square value of ($\chi^2_{12,0.05}$=35.497, P<0.05) was obtained (Table 8), which indicates that there was a significant association between the water affordability and the sub-counties.

Table 8
Chi-Square Analysis of *Affordability Based on Cost of 20L Container versus Sub-County*

Chi-Square Tests			
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	35.497[a]	12	.000
Likelihood Ratio	33.362	12	.000
Linear-by-Linear Association	5.485	1	.019
N of Valid Cases	388		

It was found that technology could have played a role in controlling the cost of water in the INSEs. According to FGD participants in Kamukunji area, the cost of water at the water automated teller machine (ATM) or Pre-Paid Dispenser (PPD) was reasonably cheap.

"*Nairobi water services through PPD self-service project provides fresh water to us at KSh. 1 per 20L jerrican. It has at least normalized water availability in the area and improved water quality*".

4.9 Water Quality Accessed by Household versus Sub-County

The study sought to determine the water quality in the various sub-counties under study. The study classified the areas into those with no quality water source and those with at least one quality source as shown in Figure 6.

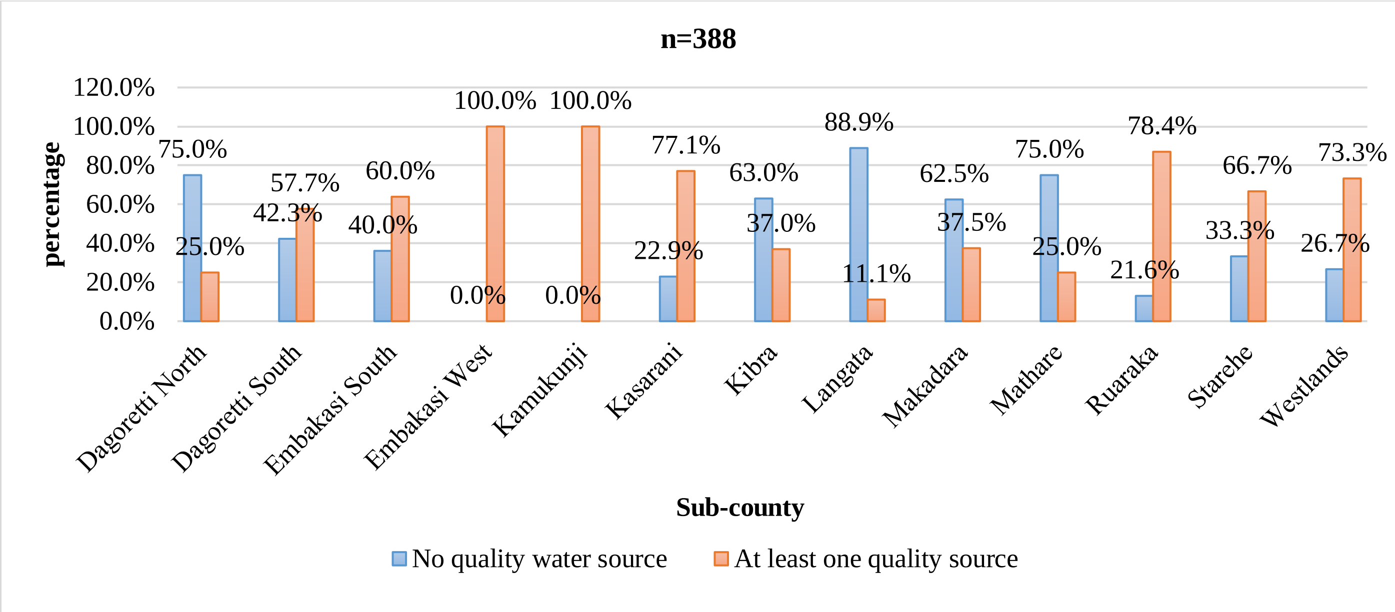

Figure 6
Water Quality Accessed by Household versus Sub-County

The sub-counties with at least one quality source of water included Dagoretti North 3 (25.0%), Dagoretti South 15 (57.7%), Embakasi South 51 (60.0%), Embakasi West 1 (100.0%), Kamukunji 14 (100.0%), Kasarani 27 (77.1%), Kibra10 (37.0%), Langata 1 (11.1%), Makadara 6 (37.5%), Mathare 4 (25.0%), Ruaraka 80 (78.4%), Starehe 10 (66.7%) Westlands 22 (73.3%). Those who had no access to any quality water source were; Dagoretti North 9 (75.0%), Dagoretti South 11 (42.3%), Embakasi South 34 (40.0%), Embakasi West 0 (0.0%), Kamukunji 0 (0.0%), Kasarani 8 (22.9%), Kibra 17 (63.0%), Langata 8 (88.9%), Makadara 10 (62.5%), Mathare 12 (75.0%), Ruaraka 22 (21.6%), Starehe 5 (33.3%) Westlands 8 (26.7%). As shown in Table 9, a chi- square value of ($\chi^2_{12,0.05}$=73.695, $p<0.05$) showed there was a significant relationship between the two variables.

Table 9
Water Quality Accessed by Household versus Sub-County

Chi-Square Tests			
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	73.695[a]	12	.000
Likelihood Ratio	73.362	12	.000
Linear-by-Linear Association	5.485	1	.019
N of Valid Cases	388		

4.10 Reliability of Water Service

The study sought to find out the reliability of water services in the area. The researcher established this through the number of days that stored water could last when there is no water supply as shown in Table 10.

Table 10
Number of Days Stored Water can last when there is No Water Supply

Number of days stored water can last	**Frequency**	**Percent**
One day	32	8.2%
Two days	45	11.6%
Three days	90	23.2%
Four days	20	5.2%
Five days	107	27.6%
More than five days	94	24.2%
Total	**388**	**100.0**

From the

Table , it can be observed that 107 (27.6%) could store for at least five days, 94 (24.2%) can store for more than five days, 90 (23.2%) could store for three days, 45(11.6%) for two days, 32 (8.2%) for one day and lastly 20 (5.2%) for four days. Ochungo et al. (2019) states that distributive efficiency is the determining factor in a water supply system's reliability. If a water distribution system can resist pressure surges and other types of failures up to a certain threshold, it is considered reliable. Three factors determine the reliability of a water works system: the amount of water provided at the correct pressure and time, the quality of that water, and whether all consumers can afford it fairly. Urban water supply unreliability is a prevalent concern, especially in developing nations, according to the study. The cost of coping is putting a significant strain on households in many regions (Ochungo et al., 2019).

The spatial nature of reliability of services was also closely linked to the presence of water cartels. These cartels undertook illegal connections or even illegally took up ownership of government installed water points, denying locals a chance to access of water. For instance, in an FGD carried out in Kamkunji, one responded said,

> *"There are too many illegal connections along the main pipeline and this has affected the pressure in the system, making the water supply un-reliable".*

Other reasons given by the FGD respondents included corruption in which case, water kiosks that had been installed in chiefs' camps were actually being sold to people when it was supposed to be accessed for free.

4.11 Water Service Reliability per Sub-County

The study determined the relationship between water service reliability and sub-county as shown in Figure 7.

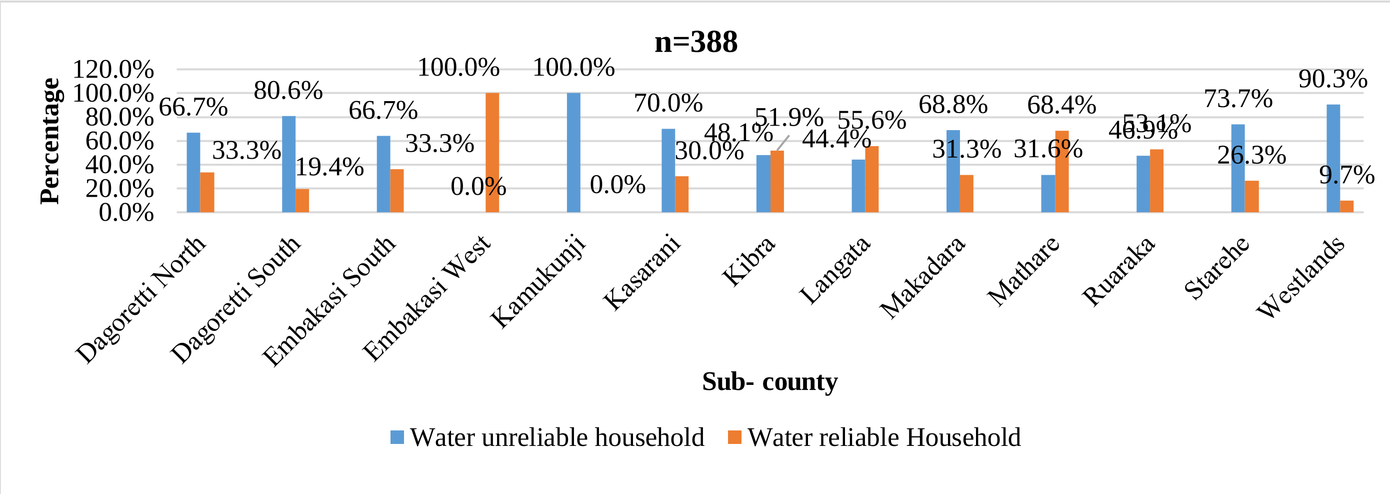

Figure 7

Water Service Reliability per Sub-County

The various sub-counties were divided into those which are water unreliable and water reliable households. From the Figure 7, those who were water reliable included Dagoretti North 6 (33.3%), Dagoretti South 6 (19.4%), Embakasi South 20 (33.3%), Embakasi West 1(100.0%), Kamukunji 0 (0.0%), Kasarani 15 (30.0%), Kibra 14 (51.9%), Langata 5 (55.6%), Makadara 5 (31.3%), Mathare 13 (68.4%), Ruaraka 43 (53.1%), Starehe 5 (26.3%), Westlands 3 (9.7%). On the other hand, those who are water unreliable included Dagoretti North 12 (66.7%), Dagoretti South 25 (80.6%), Embakasi South 40 (66.7%), Embakasi West 0 (0.0%), Kamukunji 26 (100.0%), Kasarani 35 (70.0%), Kibra 13 (48.1%), Langata 4 (44.4%), Makadara 11 (68.8%), Mathare 6 (31.6%), Ruaraka 38 (46.9%), Starehe14 (73.7%), Westlands 28 (90.3%). Table 11 shows a chi- square analysis computed as, ($\chi^2_{12,0.05}$=55.620, P<0.005) which showed that there was a significant relationship between water service reliability and sub-county.

Table 11

A Chi-Square Analysis of Water Service Reliability per Sub-County

Chi-Square Tests			
	Value	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	55.620^a	12	.000
Likelihood Ratio	59.710	12	.000
Linear-by-Linear Association	4.201	1	.040
N of Valid Cases	388		

4.12 Characteristics Breakdown of Household Water Security

From Table 12, it can be observed that in general, 210 (53.4%) of the households did not have readily available water in their households while 178 (46.6%) had water readily available overall from all sources. On households with acceptable water access 278 (71.7%) and those with unacceptable water access were 110 (28.3%). Households with sphere compliant were 294 (75.7%) while sphere non-compliant were 94 (24.3%). Households who were Non- Compliant with National Standard were 377 (97.1%) while those who were compliant with national standard were 11 (2.9%). On the other variable of water quality, the study found out that those who had at least one quality source were 250 (64.6%) while 138 (35.4%) did not have any quality water source. On water affordability, 305 (78.8%) households were standard non- compliant while those who were standard compliant were 83 (21.2%). On water reliability, households with water unreliable were 249 (64.4%) households while those who had water reliable were 139 (35.6%) households.

Table 12

Overall Status of Household Water Security

Water security variable	Status	Frequency	Percent
Availability (Household overall water availability)	Water not readily available	210	53.4%
	Water readily available overall from all sources	178	46.6%
	N	**388**	**100.0%**
Access (Water service overall access)	Unacceptable access	110	28.3%
	Acceptable access	278	71.7%
	N	**388**	**100.0%**
Quantity Sphere Standard (Sphere compliance of 15 lpcd)	Sphere Compliant	294	75.7%
	Sphere non-compliant	94	24.3%
	N	**388**	**100%**
Quantity National Standard (Household compliant with National Standard water quantity of 60 lpcd)	Non- Compliant with National Standard	377	97.1%
	Compliant with National Standard	11	2.9%
	N	**388**	**100.0%**
Quality (Household with at least one water source with acceptable quality)	No quality water source	138	35.4%
	At least one quality source	250	64.6%
	N	**388**	**100.0%**
Affordability (Standard cost per 20 litres at KSh. 2)	STD non-compliant	305	78.8%
	STD compliant	83	21.2%
	N	**388**	**100.0%**
Reliability (Consolidated water reliability)	Water unreliable household	249	64.4%
	Water reliable Household	139	35.6%
	N	**388**	**100.0%**

4.13 Overall Status of Household Water Security

As detailed in Table 13, only one household met all the criteria of being water secure by meeting all the six parameters of water security representing only 0.4%. A majority of the households, 31.8% satisfied four parameters, 30% met three parameters, 20.8% met two parameters, 11.7% met 5 parameters and 5.3% met one parameter. This pointed to a situation where water security is a major concern in Nairobi's INSEs.

Table 13

Overall Score on Water Security Characteristics

Number of water security characteristics met	Number of households	Percent
1	15	5.3
2	59	20.8
3	85	30.0
4	90	31.8
5	33	11.7
6	1	0.4
Total	**283**	**100.0**

From the research findings, there was an association between the water security factors (availability, access, quantity, quality, affordability and reliability) and sub-counties, an indication that, spatial, socio-demographic and environmental factors played a major role in attainment of water security. This was also the case for a study in Benin which highlighted socio-demographic and environmental factors as important factors in water access (Gaffan et al., 2022).

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Based on the research findings, the study came to the conclusion that water insecurity in the informal settlements in Nairobi County is rampant. The several water service providers, Nairobi Water and Sewerage Company (NCWSC), the Faith Based Organizations (FBOs)/Community Based Organizations (CBOs), self-suppliers, private borehole developers, and the intermediaries with hand carts, water kiosks, and on-sellers, are not coordinated or collaborating, leading to household water insecurity. Therefore, there is a need for an integrated response of the service providers to advance water security among those living in informal settlements in Nairobi County. The findings of this study also show that almost all households in Nairobi's informal settlements experience water insecurity. With only 0.4% of the households attaining water security, it is pointing towards a hazardous situation that may easily be disastrous if not addressed. For the informal settlements in Nairobi County, the existing water structures of the water service provision system influenced only three of the six water security factors, that is, availability, access, and quality. The level of structure did not have any impact on the quantity of water accessed by households, the affordability of the water, or how reliable the water service was. This pointed to households' coping strategies where there was dependency on multiple water sources in order to improve household water security. The study therefore concludes that the provision of infrastructure alone may not lead to household water security.

5.2 Recommendations

The study recommends that there is need for formal and informal water service providers to collaborate in order to achieve water security in informal settlements. The National, County Government and stakeholders in water sector, while planning water service provision and infrastructure development, should ensure that efforts towards attaining universal access to water through availability, access, quantity, quality, affordability and reliability should have a targeted approach to reach those who are most water insecure. Therefore, while planning the development of a water supply system structures (production, treatment, storage and distribution), the decision should be based on whether the investment will improve availability, access, quantity, quality, affordability and reliability of service. Accordingly, this decision should help inform the investment by policy makers to ensure water security.

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