Research Paper

Leaving no one behind? Analysis of trends in access to water and sanitation services in the slum areas of Nairobi, 2003–2015

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ABSTRACT

Service provision backlogs in access to improved water and sanitation services remain a key barrier to the health and well-being of people living in Nairobi's slum areas. In this paper, we use quantitative data from the Nairobi Urban Health and Demographic Surveillance System to analyze the extent to which residents of Nairobi's slum areas have been able to access improved water and sanitation services from 2003 to 2015. This trend analysis reveals a slow but observable increase in access to improved sanitation facilities and garbage disposal services, while access to improved sources of water decreased. We conclude that the best scenario is the one in which all the three indicators have significantly improved during the period under consideration rather than having only some of them improving, while the others stagnate or decline. We recommend that Nairobi City Council and sector development partners refocus their attention towards increasing access to improved water and sanitation services in the urban low-income areas because lack of access to these essential services may expose people to waterborne diseases. It also threatens to leave behind a substantial number of people as the country moves towards the attainment of the water and sanitation-related sustainable development goals.

Key words | diseases, Nairobi, sanitation, slums, water

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INTRODUCTION

Global figures that estimate the lack of access to improved water, sanitation and hygiene (WASH) services are alarming. At least 2.1 billion people are estimated to be lacking access to improved, safe and readily available sources of drinking water at home (WHO & UNICEF 2017). The lack of access to sanitation is an even larger challenge, with more than 4.5 billion people worldwide living without access to safely managed sanitation services, while about one billion people lack basic access to a sanitation facility (Andersson *et al.* 2018). It is clear that progress in achieving broad access to WASH has been slow, particularly for sanitation (Loevinsohn *et al.* 2014). In 2015, only 40% of the urban population in sub-Saharan Africa (SSA) had improved sanitation and a mere 33% had piped water in their homes (Ezeh *et al.* 2016).

The goal of achieving significant improvements in the percentage of people with access to clean water supplies and efficient sanitation services has been specifically embedded in the millennium development goals (MDGs) 2015 and the sustainable development goals (SDGs) 2030. For example, SDG Target 6.2 seeks to achieve universal access to adequate and equitable sanitation and hygiene

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for all and end open defecation, paying special attention to the needs of vulnerable women and girls by 2030. Under the SDGs, universal access is measured in terms of the size of the population living in households with access to basic drinking water and sanitation services. Thus, access to adequate water is measured through the size of the population using a safely managed drinking water source that is located on one's premises, available when needed and free from contamination (WHO/UNICEF 2017). On the other hand, access to managed sanitation services is measured in terms of the size of the population using services that enable excreta and other waste from the household to be safely disposed of *in situ* or treated off-site (WHO/UNICEF 2017).

The importance of WASH services is highlighted in the UN-Habitat's definition of a slum area which views it as a group of individuals that live under the same roof that lack one or more of the following conditions – access to improved water, access to improved sanitation, sufficient living space, durability of housing and secure tenure (UN-Habitat 2003). In slum areas, the WASH service provision backlog is substantial. It is magnified by the available statistics that present a very disappointing picture. In these areas, inadequate water supply, sanitation, drainage and rubbish collection in a crowded environment predispose the population to recurrent diarrhea and diseases such as typhoid, hookworm and cholera (Ezeh *et al.* 2016). If one compares improvements in water supply and sanitation in African slums with related improvements experienced in European and North American cities in the 19th century, it is easy to conclude that the interventions implemented in African slums have not yet yielded many substantive health benefits. It is critical that we find answers to this dilemma.

A detailed study by Development Initiatives (2018) revealed that the proportion of households with access to water from an improved source in Kenya increased from 56.1% in 2009 to 72.6% in 2015/2016. The data also show that there was no significant change in the proportion of households with access to improved sanitation services over this period, with 65% of households having access to improved sanitation services in 2009 and 65.2% in 2015/2016 (Development Initiatives 2018). These average national figures also mask the significant inequalities that exist in access to improved sanitation services across different geospatial spaces in the country. For example, in rural areas, 50.8% of households do not have access to improved sanitation services compared with only 13.2% in urban areas while in urban areas, the lack of adequate sanitation disproportionately affects poor residents in informal settlements (Development Initiatives 2018). An estimated 24% of residents of slum areas have access to household toilet facilities (which is considerably below the national average of 65.2%), while 68% rely on shared facilities and 6% have no access to facilities at all and often resort to 'flying toilets', which pose a serious health hazard (Muhele 2016).

People who live in slums often share environmental risks, such as those arising from poor sanitation, and they experience the so-called neighborhood effects (Meijer *et al.* 2012). In most slum areas, streets and lanes are unpaved with no drainage and are, therefore, converted to mud and stagnant pools when it rains. Garbage collects in huge, malodourous piles and often contains excrement. In most slum areas, gray water discharge (waste water from bathrooms and kitchens) is also quite significant, leading to serious negative effects on the environment and population health, especially effects of soil and ground water pollution (Katukiza *et al.* 2015). There are also cases where the nutrients in gray water may cause eutrophication leading to overall deterioration of ground water quality, particularly as you move away from the main roads into the more informal footpaths and tracks between the structures (Morel & Diener 2006). The neighborhood health effects of all these anomalies can be substantial. The international community might even have exacerbated the problem by setting standards for improved sanitation that are unsuitable for densely crowded slum conditions (Patel & Baptist 2012). Furthermore, slum dwellers continue to perceive WASH services as their most pressing need (Parikh *et al.* 2012). This underlines the importance of studying slum health in the context of WASH because slums are spaces where neighborhood effects are likely to exist (Ezeh *et al.* 2016).

While WASH services constitute some of the most basic requirements for human health and dignity throughout the world, this dignity is missing in most of the slum areas of Nairobi. Even though there have been a number of interventions intended to upgrade Nairobi's slum areas, focusing on issues of infrastructure development, especially in the Korogocho and Viwandani slums, the communities remain exposed to overcrowding and poverty, alcohol and substance

abuse, domestic violence and crime (Aboderin *et al.* 2017). In addition to widespread poverty, residents of Nairobi's Viwandani and Korogocho slum areas are also faced by the near-absence of most of the basic services they need to live healthy lives. It is also important to note that Kenya has experienced unprecedented urban growth, which is expected to lead to the country's urban population reaching about 31.7 million (56%) by 2027 (WSUP 2018). This rapid urbanization has left Kenyan cities with a huge unmet demand for critical infrastructure and basic services, adversely affecting the quality of life for urban residents, with nearly two-thirds of urban residents having no access to improved sanitation (WSUP 2018).

In this paper, we use quantitative data from the Nairobi Urban Health and Demographic Surveillance System (NUHDDS) to analyze the extent to which residents of Nairobi's slum areas of Viwandani and Korogocho have been able to access improved water and sanitation services from 2003 to 2015. The NUHDDS data provide a useful starting point for developing a more nuanced understanding of the major issues associated with the provision of WASH in slum areas. Results from this analysis are intended to inform the agenda of policymakers and practitioners who grapple continuously with the challenges faced in accessing WASH services in Nairobi's low-income residential areas. It also directly contributes to the growing body of knowledge on access to improved WASH services in the context of slum areas in low- and middle-income countries.

DATA AND METHODS

Location of the study sites

Data for this study were obtained from a longitudinal demographic surveillance system covering the slum areas of Korogocho and Viwandani in Nairobi. The two slum areas are located about 7 km from each other. Korogocho is roughly 1–1.5 km^2 in size and located about 11 km northeast of Nairobi City Centre, while Viwandani is about 4–5 km^2 in size and located about 7 km southeast of Nairobi City Centre.

Study design and setting

We analyzed data collected during the period 2003–2015 from the NUHDSS which was established in 2002 and is run by the African Population and Health Research Center (APHRC). It is the first urban-based longitudinal health and demographic surveillance platform in SSA established to provide space for investigating the long-term social, economic and health consequences of urban residence, and also to serve as a primary research tool for intervention and impact evaluation studies focusing on the needs of the urban poor (Beguy *et al.* 2015). The longitudinal data that have been collected from the Korogocho and Viwandani slum settlements of Nairobi enable ongoing investigation of the linkages between urban poverty, health, demographic and other socio-economic outcomes, and facilitate the evaluation of interventions implemented by the government and other development partners to improve the well-being of the urban poor (Beguy *et al.* 2015). The baseline survey that defined the initial population for the NUHDSS was carried out from July to August 2002. Since then, subsequent visits have over the years been made after every 3 months by the fieldworkers to all residential housing units in the study sites. The housing units are marked with unique identification numbers. The fieldworkers collect comprehensive data on demographic, socio-economic and health status aspects of household members. Information on household characteristics and livelihood sources are collected once a year.

Measures

Explanatory variables

Explanatory variables used in our analysis include the year of survey/interview, the slum of residence at survey (i.e., Korogocho = 1, Viwandani = 2), age and gender of household head at the time of the interview, the size of household (i.e. number of people living in the household as at survey), ethnicity (Kikuyu, Luhya, Luo, Kamba, Kisii, Garre and other), religion, the education level of household head, hunger scale and wealth index. A wealth index was constructed using principle component analysis with input as indicator variables on the ownership of household and individual assets/items (such as TV, electricity, fridge, radio, bicycle, motorcycle, shoes, blanket and clothes) and nature of their housing. The wealth index was grouped into lowest, middle and highest tertiles.

Outcome variables

We focus on three WASH variables, namely source of drinking water, type of toilet and method of garbage disposal used by the household. Following the WHO guidelines, drinking water sources and sanitation were classified into 'improved' and 'unimproved' (Yu *et al.* 2016). Table 1 presents the classification for sanitation and drinking water sources into improved and unimproved that we used to define our variables, adapted as per the WHO standard.

Table 1 | Overview of the classification of WASH indicators in the NUHDSS

	Improved	Unimproved
Drinking water source	• Piped water into dwelling, plot or yard • Public tap/standpipe • Tube well/borehole • Protected dug well with hand pump • Protected spring • Rainwater collection from the roof	• Unprotected dug well • Unprotected spring • Small water vendor (cart with small tank or drum) • Bottled water • Tanker truck • Rainwater collection from surface run-off. Surface water (river, dam, lake, pond, stream, canal and irrigation channels) • Protected dug well with bucket
Toilet facility type	• Flush/pour flush to the piped sewer system or septic tank or pit latrine • Ventilated improved pit (VIP) latrine • Pit latrine with slab • Composting toilet	• Flush/pour flush to elsewhere, for example, to open drain • Pit latrine without slab (slab with holes)/open pit • Bucket • Hanging toilet/ hanging latrine • No facilities or bush or field
Garbage disposal method	• Garbage dump • Private pits • Public pits • Proper garbage disposal services • Other organized groups such as the national youth service	• In the river • On the road, railway line/station • In drainage/sewage/ trench • Vacant/abandoned house/plot/field • No designated place/ all over • Street boys/urchins • Burning • Other

Note: Adapted from Yu *et al.* (2016).

For purposes of WASH surveys, an 'improved' toilet is normally defined as a toilet in the improved category shown in Table 1 and also one that is necessarily not shared with other families. This is to maintain consistency with other survey tools. A public toilet is one that any member of the public can use, for example, in hospitals or markets. Open use means that the toilet is accessible to anyone in its vicinity and it is often difficult to ensure its proper maintenance and cleanliness. A communal toilet is designed for a specific number of people within a particular catchment, for example, 20 or 50 people per drop hole and often people will not have a sense of ownership or responsibility for maintaining the facility unless they are mobilized to do so. A shared family toilet is one used by not more than two families and also a maximum of 12 people. A single household toilet is not shared and is usually the easiest to keep clean.

While there are other scholars who argue that shared sanitation facilities meet many of the aims of sanitation such as disease control, economic development and environmental improvement, particularly because they hygienically separate human excreta from human contact; in this paper, we argue that they fall short of the internationally agreed standards (Sulabh International 2011; Mazeau *et al.* 2014). Indeed, they could serve communities very well if collective action-related challenges that often arise in the management of common-pool resources could be effectively addressed, particularly in terms of cleaning and the maintenance of these facilities. Thus, in our view, shared sanitation facilities remain a useful approach, but should be seen as compromise solution in cases of acute scarcity rather than an ideal option meeting minimum standards.

We also note that bottled water is usually considered improved only when the household uses it by choice rather than because they are obliged to or when it can be guaranteed that this water is not contaminated. In the NUHDSS, this could not be established prior to the survey round. For water from bowsers carried on trucks to the users to be considered 'improved', the water must have been chlorinated or somehow treated or purified. In cases where water is sold from a bowser by a private contractor and chlorination cannot be established, it is considered unimproved.

For the analysis done in this paper, an '*improved*' garbage disposal system or method is defined as one implemented with potential for recycling and waste management as a resource management system, rather than just another waste management system. We have also followed WHO strategies for waste reduction, separation, processing, management and recycling, and reuse to define improved garbage disposal services. Other alternatives such as open incineration of solid waste are considered as unimproved methods.

Statistical analysis

We modeled the proportion of the study population using 'improved' drinking water supplies, toilet facilities and garbage disposal methods within a generalized linear mixed model framework. Specifically, we fitted a generalized estimating equation (GEE) to the data assuming an autoregressive correlation structure. We fitted a separate model for each of the three WASH indicators. The GEE was chosen to account for the fact that responses from the same household are more likely to be correlated than would responses from different households. Taking into account these inherent repeated measures, nature of the data is likely to result in unbiased estimates and therefore correctly inform policy formulation. We adopted a step-by-step construction of the model. First, we fitted a univariable model for each outcome and for each of the considered explanatory variables. Next, all explanatory variables that were found to be significant at $P < 0.20$ were included in a multivariable model and tested at $P < 0.05$ using the likelihood ratio test. All statistical analyses were performed using STATA v.15 (StataCorp, College Station, TX).

Ethics considerations

The APHRC submitted an application for ethical clearance to the Ethical Review Board of the Kenya Medical Research Institute (KEMRI). The NUHDSS was granted ethical clearance by KEMRI in 2002 and the clearance has been subsequently renewed over the years through annual submissions for renewal to the KEMRI Ethical Review Board.

RESULTS AND DISCUSSION

Descriptive findings

More than 67,000 people per year constituted the total sample size for the NUHDSS since 2003. Table 2 shows the NUHDSS population (number of individuals) and the number of households interviewed from 2003 to 2015. It can be observed that overall, the NUHDSS population increased by 14% from 67,850 people in 2003 to 77,347 residents in 2015. Although not shown in Table 2, population growth in this time period was higher in Viwandani at 23% compared to Korogocho at 3%. There were 85,892 distinct households in the demographic surveillance area over the period 2003–2015. In the following sub-sections, we present statistics for all the three WASH outcomes under the study.

Exploratory trend analysis

Figure 1 shows, for each of the three outcomes, the proportion of households with improved versus unimproved WASH services over the years under the study. In general, the proportion of households using improved drinking water sources dropped slowly from 97.7% in 2003 to about 95% in 2009, after which there was a faster drop to 77.5% in 2015. Conversely, the proportion of households with access to unimproved water sources steadily increased from

Table 2 | NUHDSS population and number of households interviewed from 2003–2015

Year	Number of individuals	Number of households	Number of interviewed households
2003	67,850	26,888	7,227
2004	74,122	28,994	10,160
2005	69,402	27,121	20,944
2006	70,928	27,699	14,658
2007	72,434	28,646	18,886
2008	74,209	29,644	19,482
2009	79,096	31,311	21,518
2010	82,189	32,421	23,056
2011	84,395	33,118	24,259
2012	81,902	32,270	21,795
2013	79,029	31,486	22,472
2014	77,243	30,763	22,074
2015	77,347	30,443	14,148

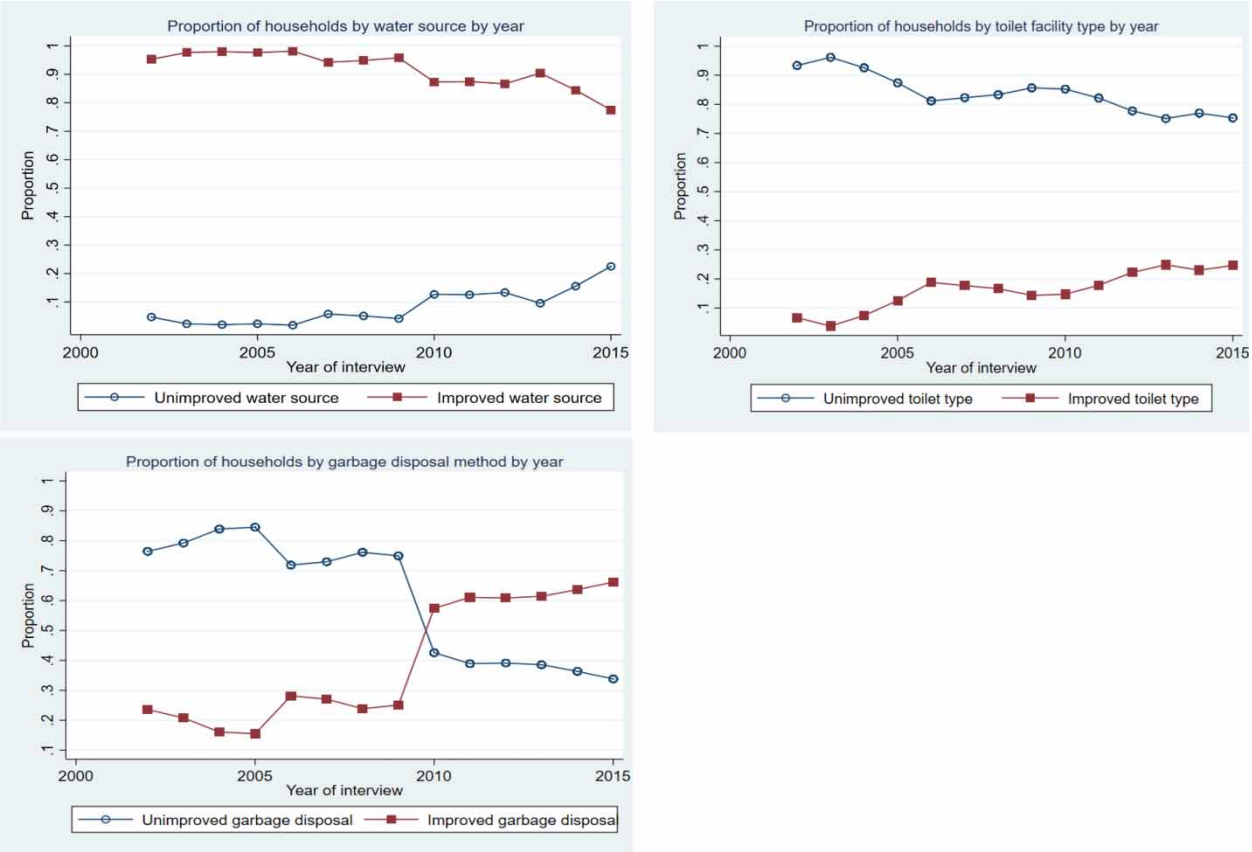

Figure 1 | Proportion of households with improved WASH facilities in Nairobi slums, 2003–2015.

2003 to 2015. Assessment for the sanitation indicator revealed that the proportion of households with access to improved sanitation facilities (toilets) slowly increased over time from 3.8% in 2003 to 24.7% in 2015. Figure 1 also shows an initial decrease in the number of households with access to improved garbage disposal services from 20.8% in 2003 to about 15.5% by 2005. This was followed by a slow increase to 25% by 2009, after which there was a sharp and significant spike in the number of households with access to an improved garbage disposal service to about 57% in 2010. Thereafter, there was a slower but steady increase in the number of households with access to improved garbage disposal services, rising to 66.2% by 2015.

Determinants of access to improved WASH services

Table 3 shows results from the GEE model. After adjusting for other explanatory factors, access to improved drinking water decreases significantly over the years. The odds of accessing an improved drinking water source were significantly lower in Viwandani than in Korogocho. Access to improved drinking water sources increased with the age of the household head as well as the size of the household. The results also indicated some variability in improved water access across different ethnic groups. The lower the food security for a household, the lower the chances of accessing improved water sources. An unexpected finding was that households in the middle and highest wealth tertiles had significantly lower odds of accessing improved drinking water sources than those in the lowest tertile.

Table 3 results also show that the odds of access to improved toilet facility increased significantly over the years, but were significantly lower in Viwandani than in Korogocho. Male-headed households had higher odds of accessing an improved toilet facility than female-headed households. However, access to improved toilet facilities

Table 3 | Adjusted odds ratios (95% confidence intervals) for all three WASH outcomes

	Water source		Toilet facility		Garbage disposal	
Variable	**OR (95% CI)**	***P*-value**	**OR (95% CI)**	***P*-value**	**OR (95% CI)**	***P*-value**
Year						
2003	1.00		1.00		1.00	
2004	0.89 (0.67–1.19)	0.439	2.20 (1.81–2.68)	<.0001	0.80 (0.72–0.89)	<.0001
2005	1.02 (0.80–1.31)	0.865	3.70 (3.08–4.45)	<.0001	0.65 (0.59–0.71)	<.0001
2006	0.90 (0.35–2.27)	0.816	7.29 (4.03–13.21)	<.0001	3.92 (2.14–7.17)	<.0001
2007	0.32 (0.13–0.82)	0.017	6.29 (3.47–11.39)	<.0001	3.72 (2.03–6.80)	<.0001
2008	0.40 (0.16–1.02)	0.055	5.38 (2.96–9.75)	<.0001	3.12 (1.70–5.71)	<.0001
2009	0.43 (0.17–1.08)	0.072	4.35 (2.40–7.89)	<.0001	3.52 (1.93–6.45)	<.0001
2010	0.13 (0.05–0.33)	<.0001	5.25 (2.89–9.51)	<.0001	14.73 (8.05–26.95)	<.0001
2011	0.14 (0.05–0.34)	<.0001	6.38 (3.52–11.57)	<.0001	17.55 (9.59–32.12)	<.0001
2012	0.12 (0.05–0.31)	<.0001	8.32 (4.59–15.09)	<.0001	16.65 (9.1–30.47)	<.0001
2013	0.19 (0.08–0.49)	0.001	10.62 (5.86–19.25)	<.0001	16.26 (8.88–29.75)	<.0001
2014	0.11 (0.04–0.28)	<.0001	9.65 (5.33–17.50)	<.0001	17.98 (9.82–32.91)	<.0001
2015	0.06 (0.02–0.15)	<.0001	11.24 (6.20–20.38)	<.0001	18.71 (10.22–34.25)	<.0001
Slum area						
Korogocho	1.00		1.00		1.00	
Viwandani	0.18 (0.17–0.19)	<.0001	0.94 (0.90–0.97)	0.001	0.95 (0.92–0.98)	0.002
Gender of household head						
Female	1.00		1.00		1.00	
Male	1.02 (0.97–1.08)	0.358	1.08 (1.04–1.12)	<.0001	0.92 (0.89–0.95)	<.0001
Age of household head (years)	1.003 (1.001–1.005)	0.002	0.995 (0.993–0.996)	<.0001	0.997 (0.996–0.998)	<.0001
Household size	1.02 (1.02–1.03)	<.0001	0.99 (0.99–1.00)	<.0001	1.01 (1.00–1.01)	<.0001
Ethnicity of household head						
Kikuyu	1.00		1.00		1.00	
Luhya	1.11 (1.04–1.19)	0.002	1.2 (1.14–1.26)	<.0001	1.13 (1.09–1.18)	<.0001
Luo	0.88 (0.82–0.96)	0.002	1.49 (1.42–1.57)	<.0001	1.08 (1.03–1.12)	0.001
Kamba	0.94 (0.90–0.99)	0.020	1.21 (1.16–1.26)	<.0001	1.04 (1–1.07)	0.027
Kisii	2.32 (2.11–2.55)	<.0001	1.57 (1.47–1.67)	<.0001	1.16 (1.1–1.22)	<.0001
Somali	3.50 (2.87–4.26)	<.0001	1.27 (1.18–1.36)	<.0001	1.80 (1.68–1.93)	<.0001
Other	1.52 (1.27–1.83)	<.0001	1.00 (0.88–1.13)	0.959	1.10 (1.00–1.21)	0.059
Hunger scale						
Food secure	1.00		1.00		1.00	
Mildly food insecure	1.11 (1.05–1.17)	0.001	1.27 (1.21–1.32)	<.0001	0.85 (0.82–0.88)	<.0001
Moderately food insecure	0.61 (0.59–0.64)	<.0001	1.42 (1.36–1.47)	<.0001	1.39 (1.35–1.43)	<.0001
Severely food insecure	0.58 (0.56–0.61)	<.0001	2.52 (2.44–2.61)	<.0001	0.77 (0.75–0.79)	<.0001
Don't know	0.64 (0.26–1.58)	0.337	1.70 (0.96–3.00)	0.066	2.71 (1.49–4.92)	0.001
Wealth tertile						
Lowest	1.00		1.00		1.00	
Middle	0.50 (0.48–0.53)	<.0001	0.72 (0.7–0.75)	<.0001	1.53 (1.50–1.57)	<.0001
Highest	0.37 (0.35–0.39)	<.0001	0.84 (0.81–0.87)	<.0001	2.21 (2.16–2.28)	<.0001

decreased significantly as the age of the household head and the household size increased. Across ethnic groups, the Luhya, Luo, Kamba, Kisii and Somali households had higher odds of accessing improved toilet facilities when compared to the Kikuyus. Similar to access to improved drinking water sources, the odds of accessing improved toilets were lower among households with lower food security as well as among those in the middle and higher wealth tertiles.

For garbage disposal, access to improved services has significantly increased over the years. Similar to water and toilet services, the odds for improved garbage disposal services were significantly lower in Viwandani than in Korogocho slum areas. Access to improved garbage disposal services also decreased with advanced ages of the household head. Male-headed households had lower odds of using improved garbage disposal, but the odds increased significantly with the household size. Luhya, Luo, Kamba, Kisii and Somali households had higher odds of improved garbage disposal services than Kikuyu households, and these odds were also higher among households in the middle and highest wealth tertiles.

DISCUSSION

The need for a better understanding of WASH service provision in Nairobi's slum areas is quite pertinent, particularly when considering that a number of interventions have been implemented in these areas. Since 2003, several WASH interventions have been implemented by various development agencies in Viwandani and Korogocho. These include toilets of various types (e.g. Biogas toilets); clean water supply and hand washing projects in communities and schools; and community-based garbage collection initiatives. Even though it is neither feasible nor desirable to carry out a direct evaluation of all the causal effects arising from these interventions, we note that some of the observed changes in WASH access trends could have been significantly influenced by these various interventions. For instance, access to improved toilets increased significantly and peaked around 2006, which coincides with the time when agencies such as the World Toilet Association, Umande Trust and APHRC implemented their own toilet construction projects in Viwandani and Korogocho. Subsequently, a trend of decreasing access to improved toilets was observable from 2007 onwards until 2010 when the proportion began to increase again. Furthermore, results from the present analysis show a slow but continuous decline in access to improved drinking water sources during the period 2003–2015 and a slow but steady increase in access to unimproved water sources particularly from 2009. This suggests that while the population in the study sites continued to increase, it was not matched by a corresponding increase in the provision of improved water sources by government agencies and other key players in the sector. Therefore, it is no wonder that many households ended up resorting to using unimproved sources. On the other hand, although the results show observable increases in access to improved toilet facilities and garbage disposal services, our findings suggest that the interventions made during the period under assessment have not been sufficient enough to address the observed infrastructural backlogs. Therefore, significant investments are still required to ensure that no household is left behind in this regard.

It is quite evident that due to the backlogs in infrastructure development, residents in the slum areas often cannot access the goods and services they need for health, education, water, sanitation and energy supply. Only 2.5% of the urban population had access to private (own-household) improved sanitation in 2014 (Mansour *et al.* 2017). In crowded slum areas, pit latrines cannot be considered as '*improved*' access to sanitation services, because their interaction with ground water and the sewer system can lead to widespread water contamination. Our findings show that traditional pit latrines in our study sites are built over a hole in the ground and these holes are unlined such that the collected fecal waste interacts with ground water directly. This has serious implications for the health and well-being outcomes of the people who live in these areas. Yet, it is commonly accepted that WASH interventions play a critical role in preventing disease outbreaks by breaking disease transmission routes (Yates *et al.* 2018). More specifically, WASH interventions can be used to prevent and control outbreaks of waterborne diseases that are normally transmitted through the fecal–oral route such as diarrhea, cholera, typhoid and hepatitis E (JMP 2014). While access to clean water for drinking and reliable sanitation services (or lack thereof) is known to constitute a

large portion of the determinants of such outbreaks, the relevant interventions in this sector are often not designed or implemented with health outcomes as their primary objective and are typically not the responsibility of health ministries (Loevinsohn *et al.* 2014).

Generally, most WASH interventions have not achieved their primary aims in many parts of the developing world, including in Nairobi. For instance, it is now apparent that piped water installations in the slum areas have been prone to contamination, and sanitation interventions have not managed to adequately remove all the waste to reduce the contamination of the environment in such a way that increasing returns to scale can be achieved. Average national figures for access to both water and sanitation presented in this paper show that the slum dwellers are trailing behind other geospatial areas in rural and urban areas. At the same time, it is possible for people who live in slums to benefit collectively from interventions for improved sanitation in very specific ways that are unique to the slum environment. Therefore, it is important to note that social and health improvement interventions that work in non-slum localities might not necessarily be readily transferable to slum areas. For example, pit latrines are now known to be especially unsuitable for slums because they allow leakage of the waste into ground water, and it is not always guaranteed that they will be lined during the construction to prevent this leakage. In addition, the pit latrines in our study sites fill up quite quickly with rainwater and flood during the rainy season. Thus, while pit latrines with slabs qualify as improved sanitation in the WHO/UNICEF definition, such facilities are often not appropriate in slum environments where the housing and population densities are exceedingly high.

The foregoing suggests that it is not enough merely to know that an intervention aimed at improving health works in order to adapt it to new situations and widen its impact. Understanding how it achieves its effects (especially how it works in practice on the ground or not) is crucial (Loevinsohn *et al.* 2014). Our study findings demonstrate that any intervention in these slum settings must also include sustainable drainage infrastructure since these settings are characterized by gray water being disposed of in open spaces. Such infrastructure might include the establishment of designated disposal points for gray water where it is treated and recycled, particularly in farming.

In essence, experiences in slum areas have demonstrated the importance of understanding one-size-not-fitting-all when it comes to WASH interventions. The number of initiatives around the world that research or implement new and innovative sanitation solutions is increasing rapidly, and a diverse set of effective onsite sanitation options now exists. This includes low-cost no-flushing toilets and source separation of waste flows (Andersson *et al.* 2018). In the face of an increasing number of potentially innovative solutions, it is important for researchers to be asking the right questions about the real and perceived bottlenecks to implementation.

In general, even though billions of people worldwide may have already gained access to basic drinking water and sanitation services since 2000 as part of the aspirations for attaining the MDGs, the coverage associated with these services has not been sufficient. It has also not necessarily always provided access to 'safe' water and sanitation services to the masses. The collective failure to achieve better WASH outcomes in Nairobi's slum areas and similar environments elsewhere in the world throws into question the effectiveness of traditional modes of WASH service delivery, including their emphasis on hardware, while also prompting a re-assessment of sector management and an enhanced interest in appropriateness of the governance arrangements in place and the political will to address evident gaps in infrastructure.

CONCLUSION

We set out to analyze and articulate the trends of WASH access in two slum areas of Nairobi based on the analysis of data from the NUHDSS, 2003–2015. Our analysis has enabled us to reach firm conclusions regarding the trends of WASH in the study sites. While there are some notable improvements, particularly in access to sanitation services, an overall assessment of all the three indicators of progress shows very slow positive change, stagnation or decline in access in some cases, which suggests that there are still considerable backlogs in the provision of WASH facilities and services in the slum areas of Nairobi. If this trend continues, a substantial number of households in the Viwandani and Korogocho slums of Nairobi are likely to be 'left behind' in terms of reaching the 2030 drinking water-related SDGs. More qualitative research is required to better articulate the

nuances of the observed decline, stagnation or increase in access to the WASH services as reflected in each of the three indicators of focus in our study sites.

Targeted policy and program interventions should be implemented which will ensure that no one is left behind as the country moves towards the attainment of the WASH-related SDGs 2030. Such interventions should seek to directly address the underlying poverty-related structural, infrastructural, socio-economic, institutional and behavioral challenges that continue to limit opportunities for improved health and well-being among slum dwellers. If access to improved WASH services for all the three indicators under our consideration in this paper is not assured, people living in the slum areas will continue to be exposed to a local environment in which waterborne diseases can easily thrive. Therefore, the best scenario is the one in which all the three indicators significantly improve over time rather than having only some of them improving while the others stagnate or decline. Failure to improve these three indicators threatens to leave behind a substantial number of people living in low-resource settings such as slum areas as the country moves towards attainment of the water and sanitation-related sustainable development goals.

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