Journal of
Water, Sanitation & Hygiene for Development

IWA PUBLISHING

 Journal of Water, Sanitation and Hygiene for Development Vol 11 No 4, 657 doi: 10.2166/washdev.2021.032

Research Paper

Latrine characteristics and maintenance practices associated with pit latrine lifetime in an informal settlement in Kampala, Uganda

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ABSTRACT

This study assessed latrine characteristics and maintenance practices associated with an extended pit latrine lifetime in an informal settlement in Kampala, Uganda. Data were obtained from 306 respondents on sociodemographic characteristics, their private pit latrine characteristics and latrine lifetime. A modified Poisson regression was used to model the latrine characteristics and maintenance practices associated with the pit latrine lifetime. All analyses were performed using Stata 14 software. Approximately 23.5% of the pit latrines had a lifetime of less than 2 years, and most latrines were reportedly desludged (64.7%) or regularly cleaned for maintenance (27.1%) as a way of extending lifetime. Pit latrine lifetime extension was higher in male-headed households (prevalence ratio (PR) 1.12, 95% confidence interval (CI) 1.00–1.25), households with a smaller number of users (unshared vs shared latrines) (PR 1.15, 95% CI 1.02–1.29) and where desludging of pits was regularly done (PR 1.53, 95% CI 1.17–1.99), while post-primary education level was negatively associated with extended latrine lifetime (PR 0.88, 95% CI 0.77–0.99). Deliberate efforts, including sensitizing communities on desludging and provision of non-shared household sanitary facilities, are needed to improve latrine maintenance and consequently extend latrine lifetime.

Key words: human waste, informal settlements, Kampala, lifetime, private pit latrines, Uganda

HIGHLIGHTS

- The design of the pit and operational management affects pit latrine fill-up rates.
- Approximately 23.5% of the pit latrines filled within 2 years after construction.
- The number of users and regular desludging of pit had a significant effect on the lifetime of pit latrines.

1. INTRODUCTION

Access to basic sanitation remains a significant challenge in low-income countries. By the end of 2017, an estimated 2.0 billion people globally lacked access to basic sanitation services (WHO 2019). Of these, approximately 693 million people in sub-Saharan Africa and south-east Asia were still practicing open defecation (WHO 2019). Currently, 828 million people live in urban slum areas (WHO & United Nations Human Settlements Programme 2010), many of whom have no access to basic sanitation (Okurut *et al.* 2014; WHO 2019).

Due to increased urbanization, informal settlements are growing rapidly, in size and population. These settlements are characterized by poor sanitation, have generally low latrine coverage and experience open defecation (Ministry of Water and Environment 2018; Ssemugabo *et al.* 2020). In such settings, pit latrines are among the most affordable sanitation products for human excreta disposal. These are popular partly because of the simplicity in constructing them with locally available materials and the ease of use, operation and maintenance (Buckley *et al.* 2008; Isunju *et al.* 2013; Jenkins *et al.* 2014). Unfortunately, in many urban centers in Africa, sanitation infrastructure is poor, and decentralized facilities, especially traditional pit latrines, are characterized by poor superstructural materials such as plastic bags, mud and wattles. Moreover,

the operation and maintenance of sanitation facilities in slums is poor (Duflo *et al.* 2012), and the infrastructural investments have also not kept pace with the rapid and unplanned urbanization further compounding the problem.

While the provision of sanitation facilities is important, their maintenance and ongoing operation are equally critical (Melorose *et al.* 2015). For pit latrines, this includes periodic removal and treatment of the accumulated sludge as well as cleaning, maintenance of the superstructure and ensuring privacy for users (Etajak 2011). In crowded communities, pit latrines need to last for a long time, since space for digging new pits is not available. In this study, we use the term 'pit latrine design lifetime' to refer to the number of years that a latrine is intended to be used before the pit is entirely full and the latrine is abandoned. We use the term 'extended lifetime' for latrines, which do not fill up within the design lifetime.

The longer the pit latrine lasts, the greater the social benefits and the lower the average annual economic cost for the users (WHO 1992; Tilley *et al.* 2014). The average lifetime of a standard pit latrine is approximately 15–30 years depending on the number of users, and operation and maintenance practices (Brouckaert *et al.* 2013; Bob Reed & Rebecca Scott 2014). However, in many low-income countries, including Uganda, slums are associated with poorly constructed latrine facilities that have a short lifetime and suffer poor operation and maintenance, especially when they are shared. In many slums in Uganda, desludging is complicated by poor accessibility to the latrines, lack of space for releasing the fecal sludge and the costs of desludging. Desludging is therefore impractical in some slum households, and where possible, contents are drained either into adjacent excavated unlined pits or into sullage drains during the rains (Barrett *et al.* 1999). In Bwaise, some households desludge pits periodically or when they get full using either a desludging pump or manual scooping with buckets. Despite this, there is still a dearth of literature on factors that determine the lifetime of latrine facilities in slum settings. The objective of this study was therefore to determine latrine characteristics and maintenance practices associated with pit latrine lifetime in Bwaise slum in Kampala, Uganda, to inform interventions, policy and practice.

2. METHODS

2.1. Study design, setting and population

This study was cross-sectional in design and utilized quantitative techniques for data collection. The study site was Bwaise III Parish, Kawempe Division, Kampala, Uganda. It is one of the most deprived slum areas in the capital city of Kampala district officially housing over 300,000 people (AFFCAD 2016). The study area, Bwaise III Parish, has six local council 1 zones (the lowest administrative unit at the local government level). The area is mainly inhabited by the urban poor who trek daily to work in jobs such as construction, bricklaying, hawking, motorcycle riding, taxi work, food vending and trading. Housing in this settlement is characterized by small semi-permanent structures constructed in a reclaimed wetland, which is mainly a flood zone. Furthermore, due to unstable soils, the area is characterized by predominantly shallow pit latrines. The study targeted all heads of households with single household pit latrines (traditional and improved). The respondents had to be at least 18 years of age and had been residents for at least 6 months.

2.2. Sample size calculation and sampling strategy

A sample size of 306 was determined using the Kish Leslie formula for cross-sectional studies (Kish 1965):

$$n = \frac{Z^2 PQ}{\alpha^2}$$

$$n = \frac{1.96^2 \times 0.75 \times 0.25}{0.05^2} = 290$$

We assumed a prevalence (p) of 75% based on the proportion of households with unimproved sanitation facilities that need lifetime extension (Kulabako *et al.* 2007). We also considered a statistical power of 80%, a 5% margin of error around the estimates. After considering a 5% nonresponse rate, the sample size increased to 306. Proportionate sampling was initially used to determine the number of households with privately owned functional pit latrines to be selected in each zone. This was done by dividing the number of households with privately owned functional facilities in the zone by the total number of households with private latrines in the whole of Bwaise III Parish and then multiplying the quotient by the predetermined sample size for this study, as shown in Table 1. We then employed a simple random sampling approach to identify households where interviews could take place in each zone.

Table 1 | Number of respondents per zone in Bwaise III Parish

	Households with privately owned functional pit latrines	Computation	Respondents
Bokasa	65	$\frac{65}{359} \times 306 = 55$	55
Bugalani	60	$\frac{60}{359} \times 306 = 51$	51
Kamalimali	59	$\frac{59}{359} \times 306 = 50$	50
Katoogo	59	$\frac{59}{359} \times 306 = 50$	50
Kawaala	38	$\frac{38}{359} \times 306 = 32$	32
St. Francis	78	$\frac{78}{359} \times 306 = 66$	66
Total	359		306

2.3. Data collection and study variables

A semi-structured questionnaire was developed and used to collect quantitative data from household respondents. An observational checklist was used to collect data on latrine characteristics such as the type of sanitary facility, state of hygiene and maintenance practices. These tools were developed by experienced environmental health experts, guided by relevant literature (Yimam *et al.* 2014; Busienei *et al.* 2019). To ensure the quality of the data collected, experienced research assistants were trained for 3 days on appropriate data collection techniques and ethical procedures.

The main outcome variable was whether the latrine exceeded its design lifetime (average period of time a pit latrine is expected to last when under use). This was a binary variable with categories 'No (or $\leq$2 years)' and 'Yes (or >2 years)', and this was based on self-reports. In our study setting, latrines that had lasted more than 2 years were considered to have an extended lifetime. The cut-off of 2 years was determined following earlier focus group discussions in which the average lifetime of pit latrines between construction and filling was taken as 2 years. Household heads were asked the age of the recently filled or nearly filled pit latrine in months, and responses were captured as a categorical variable with options as '1–5 month', ' 6–12 months', '13–18 months', '19–24 month' and '25 and above months'. These were then collapsed to a binary outcome variable ($\leq$ 24 months (2 years) and >24 months (2 years)). Those that had exceeded 2 years were considered to have taken more than the actual expected filling time (extended lifetime). Households with recently filled or nearly full pit latrines were selected for the study with the guidance of the zone or village head. The explanatory variables included social demographic characteristics including sex of the household head, education, employment status, age group, marital status and income level. There is literature suggesting differential involvement in sanitation between men and women with women more involved in cleaning, while men are mostly involved in construction and access to more resources and better incomes (Brewster *et al.* 2006). The inclusion of other sociodemographic characteristics as explanatory variables, such as education, occupation and income, was guided by a review of literature on latrine use and lifespan (Ashebir *et al.* 2013; Sinha *et al.* 2017; Chiposa *et al.* 2018).

Latrine characteristics, such as the depth of the pit latrine, presence of lined pit latrine walls and having the latrine shared among multiple households, were also considered as covariates (IFRC 2002). We also asked about respondents' knowledge of the maintenance practices of pit latrines, such as regular cleaning, periodic desludging of the pit latrine, locking the pit latrine, repair of the superstructure and the practices of dumping rubbish into the pit latrine and adding chemicals (Kwiringira *et al.* 2014; Chunga *et al.* 2016). Although locking the latrine restricts access to nonfamily members, we considered it as an independent variable since some literature suggests that it may extend latrine lifetime by limiting the number of people that use the facility (IFRC 2002). The evidence of the effect of chemical additives on volumes of fecal matter in latrines is mixed. In some experiments, they have been shown to inhibit the natural biological decomposition process in latrines, while in other cases, they have been shown to reduce volumes of fecal wastes (Barrett *et al.* 1999; Buckley *et al.* 2008). We therefore considered the use of chemical additives as an independent variable.

Data on the dependent and independent variables were obtained through interviews and where possible by direct observation.

2.4. Quality control and the design of data analysis

Questionnaires and checklists were checked by the supervisor to ensure that errors and omissions were corrected to ensure completeness and correctness. Missing data were minimized by organizing for recollection from the participants during the period of data collection.

Descriptive statistics, such as frequencies and proportions, were used to summarize categorical data, and the results presented in a narrative and tabular format. To establish the association between pit latrine lifetime extension and associated factors, a modified Poisson regression with robust error variances was used to produce prevalence ratios (PRs) and their 95% confidence intervals (CIs). During analysis, the regression models were based on PRs instead of odds ratios since odds ratios tend to overestimate the relative risk in instances where the binary outcome is common, usually with a prevalence greater than 10% such as in this case (Montreuil *et al.* 2005). Covariates that were significant at p-values of <0.05 in bivariate analysis and those with biological plausibility were included in the multivariable analysis. A stepwise backward elimination approach was applied until the final adjusted model was obtained. Variables with p-values of <0.05 were considered statistically significant. Data were analyzed using Stata 14 statistical software.

2.5. Ethical consideration

Ethical approval to conduct the study was obtained from the Makerere University School of Public Health Higher Degrees, Research and Ethics Committee (HDREC) and Uganda National Council for Science and Technology (UNCST). We also sought permission from the district health office, Kampala district and a medical officer, Kawempe division. Written informed consent was sought from each participant, and all data collected were treated with the utmost confidentiality.

3. RESULTS

3.1. Sociodemographic characteristics of respondents

Most respondents were females, 73.9% (226/306) had attained post-primary education 65.5% (207/306) and earned between 50,000 and 300,000 UGX 71.2% (225/306), while only 40.9% (127/306) of the respondents had stayed in the community for at least 1–5 years (Table 2).

3.2. Characteristics of pit latrines in Bwaise III informal settlement

Most pit latrines 81.4% (249/306) had superstructures constructed using bricks, sand and cement, and 92.4% (283/306) were roofed with iron sheets. Most latrines 78.1% (239/306) were of the type 'ventilated improved pit (VIP) latrines' (62.1% raised VIPs and 16.0% non-raised VIP latrines), and more than half 58.8% (180/306) were located within 5 m of the main house. In addition, 72.2% (221/306) of the latrines were constructed in low-lying areas, and 18% (55/306) had reinforcement to prevent them from collapsing. Approximately 62.4% (130/306) of the latrines were dirty and had visible urine and fecal matter (Table 3).

3.3. Pit latrine lifetime and maintenance practices

Almost a quarter of the pit latrines (23.5% (72/306)) had a lifetime of less than 2 years, and 76.5% (234/306) had a lifetime of more than 2 years. As a way of maintaining latrine, 64.7% (198/306) of the households periodically desludged their latrine, 27.1% (83/306) regularly cleaned around the pit latrine, 18.3% (56/306) repaired the superstructure and 6.5% (20/306) did not dump rubbish and other wastes in the latrine.

3.4. Knowledge of pit latrine maintenance practices

Regarding awareness of pit latrine maintenance practices, only 40.2% (123/306) mentioned at least four practices. Some of the most common maintenance practices included desludging 77.8% (238/306), adding chemicals 52.3% (160/306) and regular cleaning 41.5% (127/306) (see Figure 1).

3.5. Factors associated with pit latrine lifetime extension

Pit lifetime extension was statistically significantly associated with desludging, with the gender and educational status of the household head and the number of toilet users. Latrines, where desludging was routinely practiced, had a 53% higher likelihood of having an extended pit latrine lifetime compared to those with no desludging (PR 1.53, 95% CI 1.17–1.99). Moreover, latrines used by one family were 1.16 times more likely to have extended pit latrine lifetime compared to those used by more than one family (PR 1.16, 95% CI 1.02–1.32). The findings also show that male-headed households were more likely to have pit latrines with extended lifetime compared to those headed by females (PR 1.12, 95% CI 1.00–

Table 2 | Sociodemographic characteristics of the respondents

Variables	Number ($N = 306$)	Percent (%)
Sex		
Male	80	26.1
Female	226	73.9
Marital status		
Single	149	48.7
Married	157	51.3
Religion		
Catholic	98	32.0
Protestant	85	27.8
Moslem	81	26.5
Others	42	13.7
Tribe		
Baganda	247	80.7
Other tribes	59	19.3
Education level		
None or primary	99	32.4
Post-primary	207	67.6
Age group [mean (SD)] = 34.5 (11.4)		
18–29	114	37.3
30–39	108	35.3
≥ 40	84	27.5
Zone name		
Bokasa	56	18.3
Bugalani	51	16.7
Kamalimali	50	16.3
Katoogo	50	16.3
Kawaala	32	10.5
St Francis	67	21.9
Household size [mean (SD)] = 5.4 (3.0)		
<5	124	40.5
≥5	182	59.5
Household income (UGX) (USD = 3743 UGX)		
< 50,000–300,000	225	73.5
400,000–600,000	60	19.6
700,000–900,000	21	6.9
Years residing in the area in years [mean (SD)] = 11.4 (10.8)		
1–5	127	40.2
6–10	67	21.2
≥11	112	38.6

1.25). However, the proportion of pit latrines with extended lifetime was 12% lower among households where the household head had post-primary education compared to where the household heads had either no or primary education (PR 0.88, 95% CI; 0.77–0.99) (Table 4).

Table 3 | Characteristics of pit latrines

Variable	Details	Frequency ($n = 306$)	Percent (%)
Superstructure			
Materials used for making the walls	Bricks, cement and sand	249	81.4
	Timber	29	9.5
	Other[a]	28	9.1
Materials used for the slab making	Wood	21	6.9
	Cement	260	85
	Mud	25	8.1
Roofing materials	Iron sheets	283	92.5
	Others[b]	23	7.5
Materials for lining latrine pits	Lined with cement and bricks	253	95.1
	Lined with stones	13	4.9
Location and access			
Type of pit latrine	Traditional pit latrine	58	19.0
	VIP	49	16.0
	Raised VIP pit	190	62.1
	Raised traditional pit latrine	9	2.9
Distance of the pit latrine from the main house (m)	<5	180	58.8
	6–10	54	17.6
	11–15	32	10.5
	16–20	25	8.2
	>20	15	4.9
Location of the pit latrine	Wetland	14	4.6
	Low-lying flood area	221	72.2
	Dry land	70	22.9
	Raised/high land	1	0.3
Stances/doors of the pit latrine	1	89	29.1
	2	173	56.7
	3	34	11.1
	4	3	1.0
	≥5	7	2.1
Reinforcement to avoid the collapse of the superstructure	Yes	55	18
	No	251	82
Depth of pit latrine (m) Mean = 1.91 (1.60)	0.0–0.5	38	12.4
	0.6–1.9	129	42.2
	2.0–2.5	100	32.7
	>2.5	40	12.7
Hygienic status of pit latrine			
Open defecation around the pit latrine	Yes	111	36.3
	No	195	63.7
Presence of flies (at least five live flies)	Yes	165	53.9
	No	141	46.1
Cleanliness of the squat hole	Toilet clean[c]	145	47.4
	Toilet dirty[d]	161	52.6
Pit latrine smell	No smell	61	19.9
	Minor smell	42	13.7
	Too much smell	183	59.8

[a]Others included stones, iron sheets, mud, clay, water, tree poles and logs, reeds, ropes and grass thatch.
[b]Plastics, grass thatch and tin sheets.
[c]Absence of dirt, urine or fecal matter.
[d]Some presence of dirt, urine and fecal matter.

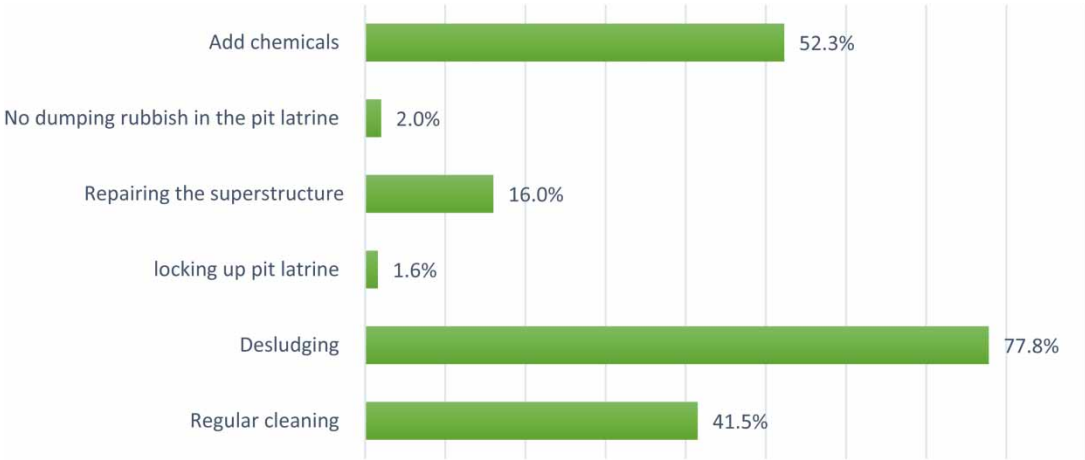

Figure 1 | Knowledge on pit latrine maintenance and lifetime extension.

4. DISCUSSION

This study investigated the latrine characteristics and maintenance practices associated with the extension of pit latrine lifetime in an informal settlement in Kampala, Uganda. The findings indicate that the most common type of latrines were the raised VIP latrines and more than half were located within 5 m of the main house. However, open defecation was high and most pit latrines were shallow, soiled, infested with flies and had foul smells. Nearly a quarter of the pit latrines had a lifetime (<2 years). The proportion of latrines with extended lifetime was significantly higher among households where regular desludging was practiced, male-headed households and those where latrines were used by members of a single family. Pit latrines owned by household heads with post-primary education were less likely to last more than 2 years.

In slum settings, because of congestion, high water table and inadequate space, continuous digging of new replacement pits once the old ones are full is not practical, and therefore, innovations and appropriate maintenance of the existing sanitation infrastructure can offer short- and long-term options for fecal waste disposal among the urban poor that are already socioeconomically disadvantaged (Nakagiri *et al.* 2016; Tilley 2014). Therefore, approaches that extended pit latrine lifetime are vital, and understanding these approaches will provide critical information that may guide sanitation policy and programs in Uganda and beyond. Our study is in line with previous studies, which have recommended the critical need of studying pit latrine lifetime (Still *et al.* 2012; Nakagiri *et al.* 2016).

A majority of the latrines were shared between families, which is a concern because the use of shared facilities has implications for maintenance in terms of potential for negligence in use and cleaning by other households. Indeed, it has been suggested that this can result in abandonment of facilities (Ssemugabo *et al.* 2020). Shared latrines are usually soiled, infested with flies, have foul odors and may encourage open defecation, which was also observed in our study. This, therefore, requires sanitation improvement programs in resource-poor settings to devise appropriate strategies for motivating slum households to construct own/non-shared latrine facilities, and where shared facilities exist, promote proper operation and maintenance.

Most latrines were located within 5 m of the main house, which is less than the minimum of 6 m recommended by the World Health Organization (WHO). The high population density of Bwaise slum makes compliance with this recommendation difficult. Moreover, owing to the high population density and limited sanitation facilities, latrines are usually unhygienic for use.

In this study, most pit latrines were well maintained by either desludging, regular cleaning or adding chemicals. Our findings paint a better picture than those established in a similar study conducted in peri-urban areas of Rwanda, Kigali, which showed that pit latrines in informal settlements were poorly maintained and rarely emptied (Tsinda *et al.* 2013). Latrine maintenance should be promoted to encourage proper use and guarantee a longer lifetime.

In this study, it was found that almost a quarter (23.5%) of the latrines had a lifetime of less than 2 years. The pit latrines in Bwaise typically last between 2 and 5 years, which is below the standard expectations of at least 15–30 years for a well-constructed, well-maintained, long-lasting pit latrine (Brouckaert *et al.* 2013; Bob Reed & Rebecca Scott 2014). This heavily

Table 4 | Unadjusted and adjusted PR ratios of factors associated with pit latrine lifetime extension

Independent variable	Pit latrine lifetime		Unadjusted PR (95% CI)	*p*-value	Adjusted PR (95% CI)	*p*-values
	Pits ≥2 years *n* (%)	Pits <2 years *n* (%)				
Overall	234 (76.5)	72 (23.5)				
Sociodemographic characteristics						
Sex						
Female	164 (70.1)	62 (86.1)	1		1	
Male	70 (29.9)	10 (13.9)	1.21 (1.07–1.35)	0.001*	1.12 (1.00–1.25)	0.050*
Respondent's education level						
Non- and Primary level[R]	83 (35.5)	16 (22.2)	1		1	
Post-primary	151 (64.5)	56 (77.8)	0.87 (0.77–0.98)	0.023*	0.88 (0.77–0.99)	0.050*
Respondents age in complete years			1.01 (1.00–1.01)	0.001	1.00 (0.99–1.01)	0.133
Employment status						
Unemployed[R]	59 (25.2)	28 (38.9)	1			
Employed	175 (74.8)	44 (61.1)	1.18 (1.00–1.38)	0.044*	1.06 (0.91–1.23)	0.440
Latrine characteristics						
Depth of the pit			1.05 (1.01–1.09)	0.014	1.02 (0.98–1.06)	0.376
Are the pit latrine walls lined						
Not lined[R]	23 (9.8)	17 (23.6)	1		1	
Lined	211 (90.2)	55 (76.4)	1.38 (1.05–1.81)	0.021	1.11 (0.88–1.41)	0.392
Toilet users						
More than one family[R]	176 (75.2)	66 (91.7)	1		1	
Family members only	58 (24.8)	7 (8.3.7)	1.25 (1.12–1.39)	<0.001*	1.16 (1.02–1.32)	0.024*
Latrine maintenance practices						
Regular cleaning of the pit latrine						
No[R]	46 (19.7)	15 (20.8)	1			
Yes	188 (80.3)	57 (79.2)	1.02 (0.87–1.19)	0.830		
Desludging for pit latrine done						
No[R]	29 (12.4)	29 (40.3)	1		1	
Yes	205 (87.6	43 (59.7)	1.65 (1.27–2.15)	<0.001*	1.53 (1.17–1.99)	0.002*
Depth of pit latrine reaches the water						
Yes[R]	186 (79.5)	55 (76.4)	1			
No	48 (20.5)	17 (23.6)	0.96 (0.82–1.12)	0.590		
Ever added any chemical						
No[R]	103 (44.0)	39 (54.2)	1		1	
Yes	131 (56.0)	33 (45.8)	1.11 (0.97–1.25)	0.137	1.03 (0.91–1.17)	0.599

*Variables significant at 5% level of significance.
R denotes reference category.

affects the provision of sanitation facilities since Bwaise is already highly congested, with inadequate space to locate more facilities. Bwaise is also a reclaimed wetland with a high water table, low-lying area and susceptible to floods (Lwasa *et al.* 2019). This, therefore, cannot permit the construction of deeper pits for latrines, which would be expected to last longer.

Latrines used by more than one family were less likely to have an extended lifetime. This is expected because when many families use the same latrines, it implies that the number of users increases as well as the amount of excreta (urine and feces) produced, hence faster filling-up of the pit. This finding is in agreement with Still and Foxon, who indicated that pit latrines

with many users are expected to fill in a shorter time than expected (Still & Foxon 2012). It is also known that different users may use different anal cleansing materials, while others may even use the pit as a site for disposing solid waste in certain areas (Buckley *et al.* 2008). Such practices can, therefore, encourage early pit filling, and hence the less likelihood for an extended lifetime.

The likelihood of having extended latrine lifetime was 1.5 times more among latrines that were routinely desludged every few months compared to those that were not desludged during the period of use. Desludging of the pit latrines is normally done to prevent latrines from filling-up by removing some of the contents. This practice has been reported to extend pit latrine life. For instance, a study by Jere *et al.* (1995) indicated that regularly desludging unlined pits could extend their lifetime by an average of 1.5 years. Evidence shows that desludging not only extends the lifetime of pit latrines but also minimizes the environmental impact of building new latrines (Yoke *et al.* 2009). Desludging should, therefore, be emphasized to increase latrine lifespan in such settings. In this study, we found out that male-headed households were more likely to have latrines with extended lifetime compared to those headed by females. This is quite surprising since women tend to pay detailed attention to household hygiene and sanitation, which could prolong latrine lifespan. The plausible explanation is that male-headed households tend to have better incomes and can provide resources that can allow for better latrine maintenance, including desludging which can help extend latrine lifespan (IFRC 2002). In Uganda, unlike households headed by men, those headed by women tend to have low incomes and, therefore, may have less money available to pay for latrine maintenance (Kwiringira *et al.* 2014). The small size of the sample of male-headed households means that this result is unreliable. Further studies with large samples may be necessary to confirm these findings.

We also found that household heads with post-primary education were less likely to have latrines with extended lifetime. It could be that their education provides them with an opportunity to engage in other jobs and hence spend less time in Bwaise and may not have time to engage in activities that would extend the pit latrine lifetime. This is, however, somewhat surprising because intuitively, we expect that higher education exposes people to better knowledge of latrine maintenance and higher income to enable activities such as desludging or emptying can extend latrine lifetime. Qualitative research may be necessary to delineate the reasons for the observed association. Although the study provides useful information on pit filling and associated factors, which is rarely studied, the outcome variable was collected as categorical variable which affects the precision of the estimates because the differences in filling time can be masked by binary categorization. Future studies need to consider this as a continuous variable.

5. CONCLUSION

Bwaise is typical of a dense informal settlement, and there are many similar places in sub-Saharan Africa. In Bwaise, the most common pit latrines were VIP latrines, but most are shallow, soiled, infested with flies and had foul smells. Open defecation remains common.

Most pit latrines had lifetime less than the envisaged 15 years for non-slum settings. There were almost no example of a pit latrine that was well maintained by a single household over its design life. Regular desludging is critical to ensuring latrines exceed a 2-year lifetime. Other household factors, including levels of education, have surprising impacts on the sustaining of latrines beyond a short timeframe.

ACKNOWLEDGEMENTS

The authors appreciate the participants, local authorities and research assistants for their role in conducting this study.

AUTHOR CONTRIBUTION STATEMENT

J.B.M. conceived the original idea, collected the data, analyzed the data and wrote the initial draft of the manuscript. S.T.W. collected the data, analyzed the data and provided critical review and editing. S.E. supported data analysis, writing of initial draft and provided critical feedback. T.S. provided supervision, provision of critical feedback and editing. J.B.I. wrote the initial draft and critically reviewed and provided feedback. C.K. wrote the initial draft, critically reviewed and provided feedback. M.O. wrote the initial draft, critically reviewed and provided feedback. D.K. wrote the initial draft, critically reviewed and provided feedback. J.S.M. wrote the initial draft, critically reviewed and provided feedback. A.A.H. was involved in planning the study, supervised data collection and provided critical feedback. J.C.S. provided critical feedback, editing and supervision. R.K.M. was involved in planning, supervision, provided critical feedback, editing and supervision.

FUNDING

This study did not receive any external funding.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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First received 24 February 2021; accepted in revised form 2 June 2021. Available online 14 June 2021