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Performance of pit latrines in urban poor areas: A case of Kampala, Uganda

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ABSTRACT

In many urban poor areas of Sub-Saharan Africa (SSA), demand for human excreta disposal is met, predominantly by pit latrines. This study aimed at determining the status of pit latrines (design, construction, operation and maintenance) and its influence on latrine performance (filling, smell and insect nuisance). The study was conducted on 130 pit latrines in typical urban poor areas of Kampala, Uganda. Data on design, construction, usage, operation and performance of the pit latrines was collected by interviews, observations and measurements; and analysed by descriptive statistics, bi-variate analysis and logistic regression. Results showed that the level of pit content was predicted by rain or storm water entry, terrain, cleaning before or after use and number of households using the latrine. Smell was predicted by cleanliness, stance length, superstructure material and whether the latrine was private or public. The predictor of presence of flies was the superstructure material. To improve the performance of pit latrines in urban poor areas, researchers and practitioners should develop local latrine design standards (dimensions, construction materials and number of users) and cleaning guidelines for local policy makers to implement.

1. Introduction

Access to improved sanitation in urban poor areas of developing countries is low. Urban poor areas, commonly referred to as slums, are heavily populated areas, characterised by substandard and unplanned infrastructure, poverty, and lack basic services like water and sanitation (Struyk & Giddings, 2009; UN-HABITAT, 2009). Human excreta disposal in urban slums of Sub-Saharan Africa (SSA) is predominantly by use of pit latrines (Katukiza et al., 2012; Thye, Templeton, & Ali, 2011). Pit latrines have been adopted and are used because of their low cost, simplicity of construction and ease of operation and maintenance. However, their use in urban slums is characterised by several challenges. Jenkins, Cumming, Scott, and Cairncross (2014) reported that some of the pit latrines in Tanzania did not meet the criteria of hygiene, safety and sustainability of sanitation systems because they were full or overflowing. Pit latrines in central Tanzania, were found to have high numbers of *Culex quinquefasciatus* mosquitoes, *Chrysomya putoria* and *Psychodidae* fly families (Irish, Aiemjoy, Torondel, Abdelahi, & Ensink, 2013). In Kenya, Caruso, Dreibelbis, Ogutu, and Rheingans (2014) found that the disgusting smell of latrines prevented their use by primary school pupils. Smell, flies and high filling rates are problems that have been associated with pit latrine use in Kigali, Rwanda (Tsinda et al., 2013). In slums of Kampala Uganda, Kwiringira, Atekyereza, Niwagaba, and Günther (2014a) reported high pit filling rates and smell as barriers for latrine usage and subsequently open defecation. Earlier, Tumwebaze, Orach, Niwagaba, Luthi, and Mosler (2012), faulted smell as one of the reasons for user dissatisfaction with use of their pit latrines.

Understanding the design, construction, operation and maintenance of pit latrines within urban slum contexts could help come up with strategies to improve their performance in these settings. Research has shown that the presence of a door, superstructure quality (in terms of height and construction materials for walls) as well as the slab type, affect the cleanliness of a latrine (Sonego &

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Mosler, 2014). Absence of a roof over the latrine and temporary superstructures as opposed to brick superstructures positively correlated with high numbers of flies (Irish et al., 2013). Relatedly, models on pit latrine filling have shown that adding non-degradable material into the pit and water inflows significantly influenced its filling (Brouckaert, Foxon, & Wood, 2013; Todman et al., 2014). Although not statistically related, smell has also for long been known as a proxy for dirty toilets.

The aim of this paper is therefore to determine the status of pit latrine structures, in terms of design, construction, operation and maintenance and the influence of these factors on their performance (filling, smell and insects nuisances) in a typical urban slum area.

2. Materials and methods

2.1. Study area

This cross-sectional study was conducted in Kampala, the capital city of Uganda. Kampala has a population of 1.79 million people (UBOS, 2013), of which about 60% resides in slums (Rugadya, Nsamba-Gayiiya, & Herbert, 2008). This research is part of a study being undertaken to enhance the performance of pit latrines in slums of Kampala Uganda, focussing on Lufula Zone in Bwaise II Ward/parish, Kawempe Division. To get information more representative of Kampala, other zones within Bwaise II parish and slums spread across the five divisions of Kampala, which are known to house different ethnic groups were included in this research. The slums outside of Bwaise II were, Kasubi in Rubaga Division; Naguru-Godown and Kinawataka in Nakawa Division; Kifumbira in Kawempe Division; Kisenyi in Central Division and Namuwongo in Makindye Division (Fig. 1).

2.2. Data collection

Data was collected from traditional/simple and ventilated improved pit (VIP) latrines, which are used by 95% of the households in slums of Kampala (Tumwebaze et al., 2012). All (38) pit latrines, were assessed within Lufula zone, Bwaise II. In addition, 44 pit latrines were randomly selected and assessed in the other zones of Bwaise II and 48 from other slums of Kampala, outside of Bwaise II. In total, therefore, 130 pit latrines were studied.

Information in this study was obtained through field observations, measurements and user interviews. Data collected during observations and measurements of the pit latrines included facility design, stance size, materials used for construction, the structural condition of the latrine, presence of bad smell, and flies or other insects. Presence of bathroom, hand washing facilities and areas used for disposal of greywater were also noted. In addition, whether or not, the latrine had an access manhole for pit emptying was also noted. All information obtained was recorded in a pit latrine design assessment sheet. Questionnaires were used to record information obtained during the user interviews. The interview addressed the ways in which the pit latrines were operated, including public or private use, numbers and types of users, and the materials other than excreta, which were put in the pit. The details on latrine maintenance (cleaning and what is done when they are full) and user satisfaction were also noted.

2.3. Data analysis

The data were analysed using SPSS version 21. Descriptive statistics mainly percentages, means and standard deviations were used to describe the status of the pit latrines. Bivariate analysis (cross-tabulation and correlation) was used to establish variations within performance of pit latrines. The relationship between performance of pit latrines and their status was determined by binomial logistic regression, whereby a best fitting model was created, from which variables useful in predicting the performance factors were identified. The variables used in the regression analysis are listed in Table 1. All conditions for logistic regression including linearity and multicollinearity were satisfied. The difference in performance of the pit latrines between the flooded and non-flooded areas plus the different latrine design types was assessed using the ANOVA at a significance level of 95%.

3. Results

3.1. Design and construction of pit latrines

The design, construction and structural condition of a pit latrine are important to ensure its proper functioning. The pit latrines in this study were all rectangular in shape, with VIPs and simple/traditional types at about 23% and 77%, respectively (Table 2). These were mainly built out of brick and plastered (77%), with timber doors (89%) and corrugated iron roofing sheets (91%) although there existed facilities with either polyethylene or mud and wattle walls (Table 2). The vent pipes of the VIPs were all made out of uPVC, mainly grey in colour (87%) and located within the superstructures (93%). Additionally, all vent pipes lacked fly screens. Fig. 2 shows existing pit latrine structures within the study area. Majority of latrines were constructed using strong and durable materials which met the recommended standards.

The number of stances per pit latrine ranged from 1 to 10, with a mean value of 2 (Table 3). The brick built structures had up to 10 stances, while timber, polyethylene, mud and wattle and roofing structures were limited to 2 stances. All pit latrine superstructures were placed directly above the slab. The slabs were all squat type, majority made of concrete (95%) of which only 10% were found to be smooth (Table 2). The minimum drop-hole length was 180 mm and the maximum width was 150 mm (Table 3).

The latrine slabs were placed directly over a single pit that was either sunk in the ground (36%) or elevated above the ground to a mean height of 935 mm (Table 3). Raised pit latrines were found in both terrains (Table 4), although the number and height of pit were significantly higher ($p \leq 0.001$) in the flooding areas. Elevated pits were all constructed using plastered brick work. Access to the elevated pit latrines was by concrete steps (61%), ramp (10%) or ladders (25%) and in some cases none (4%). Some pit latrines (47%) were constructed with an attached bathroom stance (Fig. 2), majority of which (82%) were discharging their grey water into open drains. Almost all pit latrines (98%) lacked hand washing facilities.

Thirty nine percent of the pit latrines had cracks while 40% showed signs of rain or storm water entry (Fig. 3). This indicates that some of the latrines were not structurally sound. Significant differences were noted between the structural condition of pit latrines in both terrains ($p \leq 0.001$) with more latrines having cracks and showing signs of rain or storm water entry in flooding areas. With regard to the construction materials, most of the plastered brick structures were structurally sound while more of the non-plastered ones showed signs of collapse and rain or storm water entry. All polyethylene and mud/wattle structures showed signs of collapse and rain or storm water entry (Fig. 3).

3.2. Operation and maintenance of latrines

Operation and maintenance of a pit latrine is crucial for its performance. Majority of the pit latrines (85%) were operated as private to households, shared by mostly 5–8 households, although up to 20 households were found using a single latrine stance. The

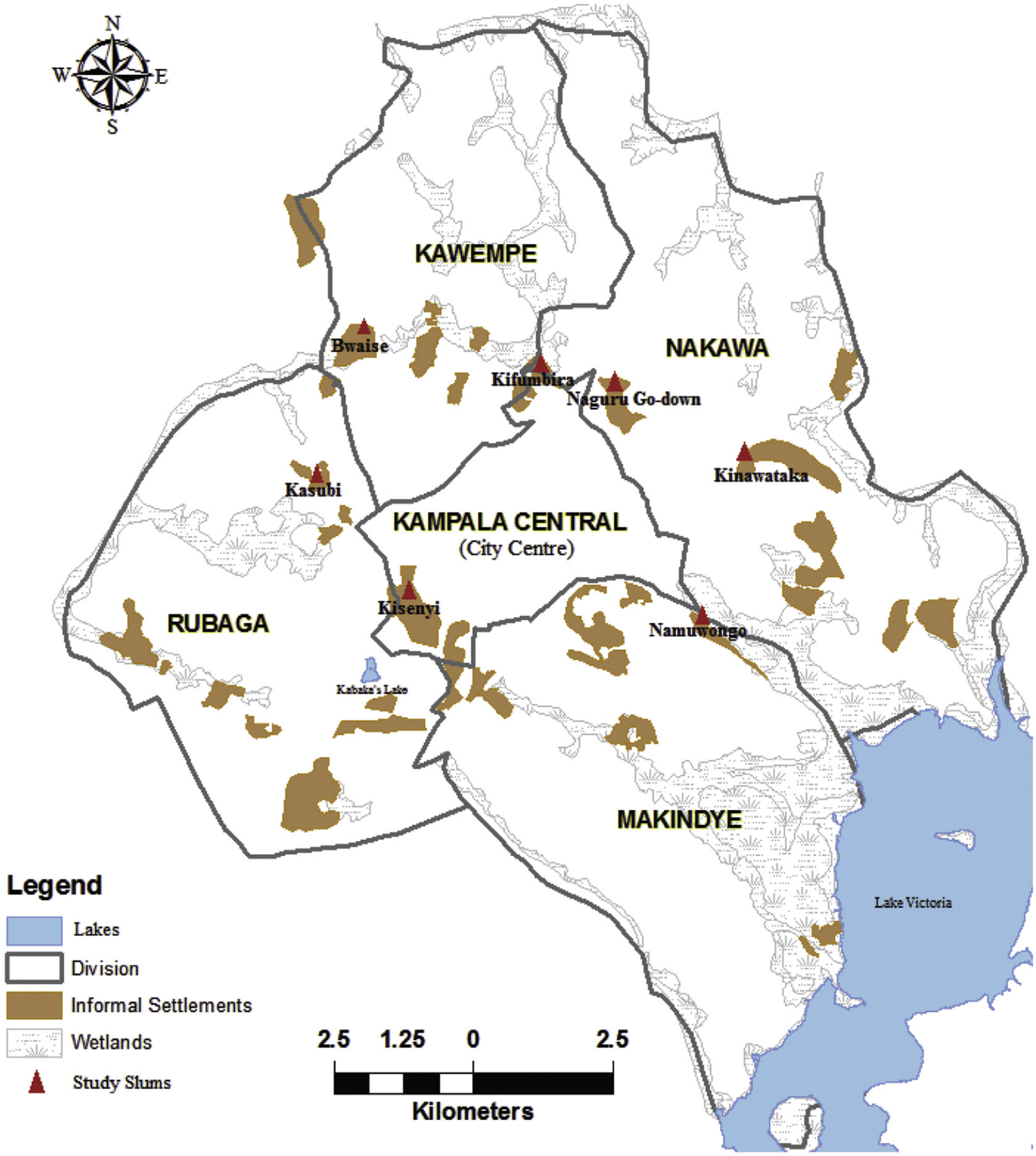

Fig. 1. Map of Kampala Capital City showing the study slums.

use of pit latrines as public facilities was at only 15%. The mean number of people per household was 4.5. Children were present in majority of the households while only 8% of the respondents stated having elderly in their homes and 4% lived with people with disabilities (PWD). The use of pit latrines by children, elderly and PWD in this study was reported by 12% of the respondents.

Human excreta, sanitary products (baby diapers and menstrual pads), and anal cleansing material (85% of which were newspapers) were deposited in the pits. Very few respondents (4%) reportedly disposed solid waste/rubbish in the pit latrines. The solid waste was dumped besides pit latrines as shown in Fig. 2. Pit latrine cleaning was by use of water and detergents that ended up in the pit. Cleaning was mainly done (66%) before or after each use of the latrine and by every user (75%). Almost all the pit latrines (95%) contained their excreta until they were emptied. The rest discharged directly into open drains and these were all found in flooding areas. Additionally, pits in non-flooding areas were constructed as leach pits while those in flooding areas were said to be fully lined. Majority of the pit latrines had a filling time of 1–3 months, with longer filling time experienced in latrines located in non-flooding areas (Fig. 4a). Upon filling, 59% of the pit latrines were reportedly emptied, while 11% of the users supposedly dug new pits (Fig. 4b). Only 5% of the latrines were constructed with access manholes for emptying.

3.3. Performance of pit latrines

Majority of the latrines were full (51%) or overflowing (15%) (Table 5). A strong malodorous smell was noted in 39% of the latrines while few flies were found in majority (80%) of the latrines. Most of the latrines (43%) were dirty. Although respondents' satisfaction with the use of their facilities was high (52%), majority of them (89%) expressed the need to improve the state and performance of the pit latrines.

Comparison of means between pit latrines in different terrains (flooding to non-flooding) showed a significantly higher level of pit

Table 1
Variables used in the logistic regression of pit latrine performance.

Study aspect	Variable name (factor)	Scale (points)	Description	Parameter coding (1)	Parameter coding (2)	Assessment used
Design and construction	Type of pit latrine	2	Simple or traditional – basic pit with a slab and superstructure; VIP – pit latrine with a vertical vent pipe	0 = Simple or traditional 1 = VIP		Observation
	Type of slab	4	Slab material	0 = logs and mud; timber 1 = Smooth; cracked concrete slab		Observation
	Drop hole cover	2	Cover on hole in the slab	0 = no cover 1 = cover		Observation
	Vent pipe	2	Vertical pipe from the pit	0 = no vent pipe 1 = vent pipe		Observation
	Superstructure walls	5	Material used for construction	1 = mud and wattle, polyethylene 0 = others 0 = Brick structures	0 = other 1 = Timber, roofing sheets 0 = others	Observation
	Doors	5		0 = Timber, metallic, roofing sheets 1 = polyethylene, none		
	Roofing	3		0 = roofing sheets 1 = polyethylene, none		
	Pit type	2	Ground level – Slab < 200 mm above the ground Raised – Slab > 200 mm above the ground	0 = Ground level 1 = raised		Measurement
	Nature of pit	2	Direct discharge (as shown in Fig. 2b), pit placed above and discharging into the drain. Containment pit (Fig. 2a and c), stores waste until it is emptied.	0 = direct discharge 1 = containment		Observation
Structural condition	Sign of pit latrine collapse	2	Cracks in the latrine structure	0 = no cracks seen 1 = cracks seen structure		Observation
	Sign of rain or storm water entry	2	Entry of rain or storm water into the pit	0 = no rain or storm water entry 1 = rain/storm water entry		Observation
Operation and maintenance	Private or public latrine	2	Public- facility open to everyone Private – use restricted to households it serves	0 = public 1 = private		Interviews
	How often the latrine is cleaned	3	When cleaning is done	1 = before or after use 0 = others 0 = daily	0 = others 1 = when dirty 0 = others	
Terrain	Non-flooding area	2	Area with a low ground water table and does not flood in the rainy season.	0 = non-flooding area		Assessment and interviews
	Flooding area		Located in a low- lying terrain with a high ground water table (<1.5 m) and always experiences floods in the rainy seasons.	1 = flooding area		
State and performance	Level of pit content	4	Almost empty – greater than two metres below the slab; Half full- about one metre below the slab; Full – 250 mm below the slab; overflowing – slab level and above.	0 = empty, half full 1 = full, overflowing		Measurement
	Latrine cleanliness	4	Very clean – no liquid, solid on slab and walls; Fairly clean – some liquid on the slab Dirty – some human excreta on the slabs and walls of the latrine: Very dirty – considerable amount of liquid and solid material on slab and wall of the latrine.	0 = clean, fairly clean 1 = dirty, very dirty		Observation
	Latrine smell	5	No smell Slight smell – little smell detected when within the superstructure Moderate – smell detected when you are in the latrine Strong smell – smell detected when outside the latrine; Very strong smell – smell detected about 1 m away from the latrine	1 = no smell, slight smell 0 = moderate, strong and very strong smell		Observation
	Latrine flies	3	No flies Few flies Very many	0 = no, few flies 1 = many flies		Observation
	Covariates					
Pit latrine design and construction	Latrine stance		Room on a latrine with a drop hole			Observation
	Stance length		Distance from the door to the back of the latrine			Measurement
	Stance width		Distance from wall to wall			Measurement
Operation and maintenance	Households using the latrine		Households using the pit			Interviews

Table 2
Design and construction materials of pit latrine structures.

Variable (n = 130)	Category	Number	Percentage (%)	Recommended standards (Franceys, Pickford, & Reed, 1992; Mara, 1984; Wagner & Lanoix, 1958)
Pit latrine type	VIP	30	23	
	Simple/traditional	100	77	
Pit latrine shape	Rectangular	130	100	Rectangular, circular
Superstructure walls	Plastered brickwork	100	77	Bricks/blocks, stone, sawn timber, bamboo,
	Brickwork – not plastered	16	12	mud and wattle, Ferro-cement, plasticised
	Timber	7	5	material and galvanised/aluminium sheets
	Roofing sheets	2	2	
	Polyethylene	4	3	
	Mud and wattle	1	1	
Roofing	Roofing sheets	119	91	Thatch, palm leaves, clay tiles, fibre cement,
	Polyethylene	6	5	wood shingles and corrugated iron/aluminium
	None	5	4	
Doors	Timber	116	89	Sawn timber, metal and no door in case of
	Metallic	1	1	spiral structures
	Roofing sheets	2	2	
	Polyethylene	4	3	
	None	7	5	
Slab type	Concrete smooth finish	13	10	Reinforced concrete/brick-mortar, wood,
	Concrete cracked	111	85	timber and earth, fabricated slabs and plain
	Logs and mud	5	4	concert slabs – for only simple pit latrines
	Timber	1	1	
Pit type	Raised pit	83	64	Raised pit (high water table, un even ground),
	Ground pit	47	36	else ground level
Nature of pit	Containment	126	97	Containment pit
	Direct discharge into drains	4	3	
Vent pipe[a]	Vent has a fly screen	0	0	Fly screen on vent pipe
	Grey uPVC	26	87	Black colour, uPVC, brick/block and hollowed
	Orange uPVC	4	13	out bamboo

[a] n value for vent pipe = 30.

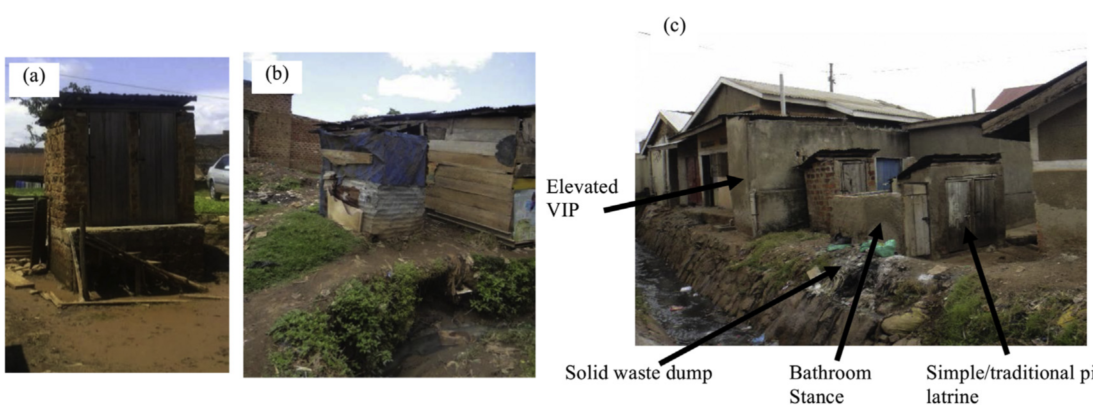

Fig. 2. Pit latrine structures in Kampala urban slums (a) Elevated pit latrine in a flood prone area in Bwaise II Parish (b) Pit latrine constructed over and discharging directly into an open drain in Namuwongo (c) Elevated ventilated pit latrine and a simple pit latrine with an attached bathroom located in a non-flooding area.

Table 3
Pit latrine measurements.

Variable	*N*	Min.	Max.	Mean	SD	Recommended standard (Franceys et al., 1992; Mara, 1984; Wagner & Lanoix, 1958)
Stances number	130	1	10	2.4	1.5	
Stance dimensions						
Length (mm)	130	700	2060	1186	254	
Width (mm)	130	500	1800	918	206	
Height (mm)	130	1670	2200	1990	282	≥2000
Drop hole dimensions						
Length (mm)	130	180	250	226	25	≥350 (to prevent soiling the drop hole)
Width (mm)	130	100	150	114	22	≤200 (to prevent children from falling in)
Vent pipe dimensions (mm)	30	100	150	107	17	≥150 (for uPVC)
Height of stance above the ground (mm)	81	400	2000	935	412	

Notes: *N* = number, Min. = minimum, Max. = maximum, and SD = Standard deviation.

Table 4
Pit type and condition of pit latrines (n = 130).

Variable	Category	Flooding area (%)	Non-flooding area (%)	Total (%)
Pit type	Raised pit	49	15	64
	Ground level pit	4	32	36
Structural condition of the pit latrine	Signs of collapse	28	11	39
	no signs of collapse	25	36	61
Storm water entry	Signs of rain/storm water entry	30	10	40
	no signs of rain/storm water entry	23	37	60
Total Pit latrines		53	47	100

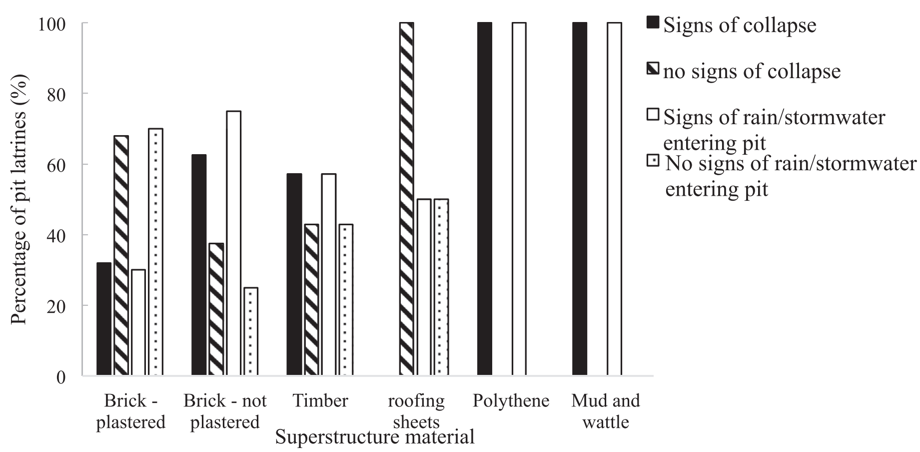

Fig. 3. Structural condition of different pit latrine superstructures.

content (p = 0.036) and smell of pit latrines (p = 0.031). Further, analysis was undertaken to assess the performance (smell and flies) of the different pit latrine designs (Fig. 5). A comparison of performance variable means of the different pit latrine designs was only significant for smell. Significantly higher smell levels were noted in traditional compared to the VIP and simple pit latrines.

3.4. Relating status of the pit latrines to their performance

A logistic regression was performed to ascertain the effects of different design, construction operation and maintenance variables on the likelihood that pit latrines were full, smelling or had flies. The results of the values of the chi-square distribution for the 3 models (level of pit content, smell and fly nuisance) were all significant at 5% level (Table 6). The models explained 59%, 75% and 51% (Nagelkerke R^2) of the variance in the pit content level, smell and flies in the latrines respectively, indicating a moderately strong relationship between the predictors and performance variables.

The Wald statistics demonstrated that signs of rain/storm-water entry ($\beta = 34.6$), flooding area ($\beta = 5.3$), and cleaning before or after use ($\beta = 5.0$) had a statistically significant relationship with the level of pit content. The odds that a pit latrine with signs of storm water entry being full are higher than those without signs. Pit latrines located in flooding areas were also more likely to be full than those in non-flooding areas, while frequently cleaned latrines (every before/after use) had a higher level of pit content.

Cleanliness was the strongest predictor ($\beta = 97.6$) of smell, implying that a dirty pit latrine was 97.6 times more likely to smell badly than a clean one. Other predictors with a notable small influence on smell were the stance length ($\beta = 1.0$), superstructure material (timber or roofing sheets, $\beta = 0.01$), latrine use by households only ($\beta = 0.01$) and cleaning before/after use ($\beta = 0.02$).

The predictor of fly presence was superstructure material ($\beta = 70.6$). Timber/roofing sheet superstructures were more likely

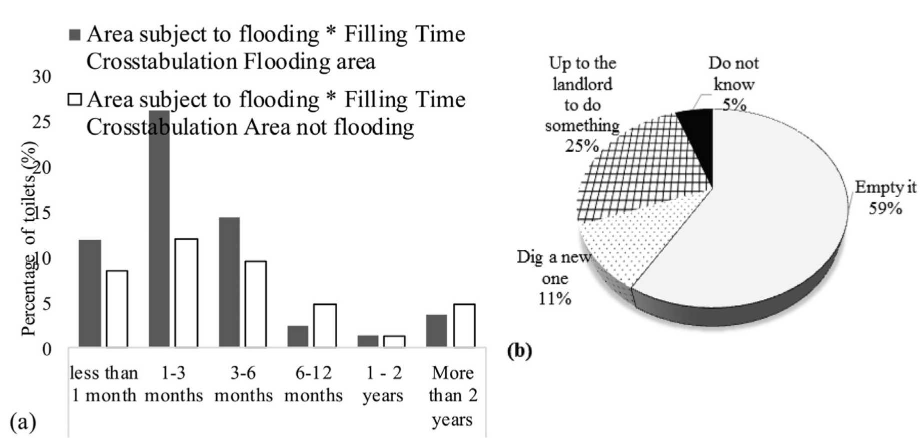

Fig. 4. (a) Pit latrine filling time; and (b) frequencies of action taken when the pit latrine is full.

Table 5
Performance of pit latrines.

Performance variables	Pit latrines (%)
Level of pit content	
Almost Empty	7
Half full	27
Full	51
Overflowing	15
Smell of Latrine	
No smell	2
Slight smell	35
Moderate smell	22
Strong smell	39
Very strong smell	1
Fly presence	
No	3
Few	80
Many	17
Cleanliness	
Clean	18
Fairly Clean	22
Dirty	43
Very Dirty	18
User Satisfaction	
Yes	52
No	48

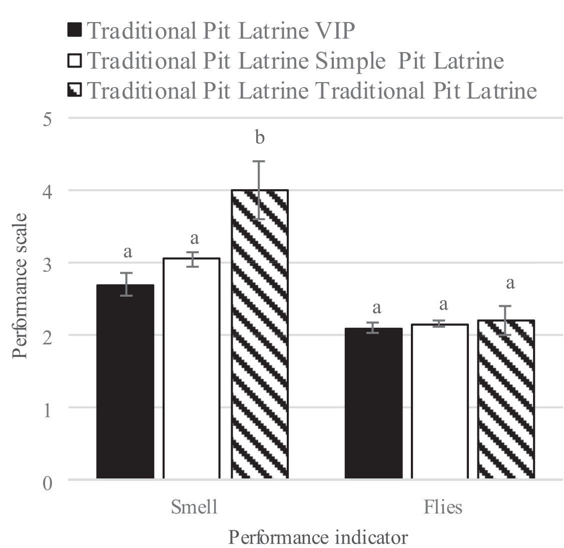

Fig. 5. Smell and fly levels (Mean ± Standard error) in the different pit latrine designs within the slums. Means with different letters for perceived levels are significantly different ($p < 0.05$).

to have flies than those made of brick. Other variables that could influence the fly presence at a low significant level ($p < 0.1$) were flooding areas and signs of collapse (Table 6).

The type of the pit latrine; its slab; presence of a drop hole cover; having a vent pipe; door and roofing material; nature of the pit; number of stances; stance width and number of households using the latrine were not significant predictors of the performance of the pit latrines. Although some of the variables were non-significant predicators, they significantly correlated with the performance of the pit latrines and can thus influence it. For instance, significant Pearson correlations were noted for containment pit ($r = -0.249$, $p < 0.001$) and pit elevation ($r = -0.240$, $p < 0.001$) with the level of pit content.

Binomial logistic regression analysis was carried out to predict the influence of the status of pit latrine structures on their performance in Lufula Zone in Bwaise II Ward/parish, Kawempe Division (Table 7). The results of the values of the chi-square distribution were significant for only the level of pit content and smell of the latrines. This indicates that the models including the predictors, significantly predict only the level of pit content and smell of the pit latrines.

Nagelkerkes R^2 indicated a moderately strong relationship between the predictors and smell (65%) and a weak relationship for level of pit content (37%). The main predictor of level of pit content was the number of households using the latrine. Other significant variables that did not contribute to the models ability to predict the level of pit content were flooding area and signs of rain or storm water entry. Smell was predicted, first by whether the pit was above the ground, followed by latrine cleanliness while fly presence had no significant predictors. Comparison of the results of slums in this study as a whole to those of Lufula zone (Tables 6 and 7) indicates possibility of having different predictors of pit latrine performance between slums.

4. Discussion

4.1. Status of pit latrine structures

Majority of the pit latrines were simple or traditional, with only three VIPs in every 10 latrines. The design adapted consisted of a rectangular brick superstructure, with timber doors and roofing sheets, having single or multiple stances over a squat type slab placed directly above a single pit (Fig. 1). From the technical perspective (Cotton, Franceys, Pickford, & Saywell, 1995) and the JMP classification of sanitation facilities (UNICEF & WHO, 2008), majority of the facilities in this study could be considered as improved pit latrines. However, there were differences and shortfalls in their construction, usage and performance.

In this study, raised pit latrines were also found in non-flooding area, perhaps due to the need for increasing the pit volume as siting new pits in slums is a challenge. The VIP latrines in this study did not meet the recommended design standards. Further, findings show that the use of polyethylene and mud/wattle structures may not be appropriate for urban slums. Majority of the pit latrines in this study were satisfactory for use by children as they had solid concrete slabs and a drop hole width less than 200 mm (Franceys et al., 1992; Mara, 1984). However, access to pit latrines by PWD and the elderly was least considered in the design. Ramps were limited to only 10% of the pit latrines. This could be due to the low occupancy of PWD and the elderly within the households. Factors that could also have hindered proper construction of pit latrine structures are limited funds, lack of design knowledge and no enforcement to ensure good facilities (Medland, Cotton, & Scott, 2015).

The performance of pit latrines in this study was found to be inadequate. Seven in every ten pit latrines were either full or overflowing and majority of them filled in three months or less. The smelling nature of pit latrines and the presence of flies, which this study found, are consistent with findings from other studies conducted in urban slum settings (Irish et al., 2013; Jenkins et al., 2014; Kulabako, Nalubega, Wozei, & Thunvik, 2010). The use of full, smelly pit latrines that also have flies, is not only difficult but also risky to the health of the users as excreta is not properly isolated.

The use of private pit latrines shared by a number of households noted in this study is typical in slums of Kampala (Kulabako et al., 2010; Tumwebaze et al., 2012). Only about three in every ten latrines were used by the recommended four households according to the Uganda's national sanitation guidelines (MOH-Uganda, 2000), and less by two household threshold recommended by UN Habitat (UN-HABITAT, 2006). This signifies that pit latrines in urban slums of Kampala are over loaded.

Table 6
Logistic regression predictors of level of pit content.

Predictor variables		Performance variables					
		Level of pit content		Smell of pit latrine		Fly presence	
		B(SE)	Odds Ratio	*B(SE)*	Odds Ratio	*B(SE)*	Odds Ratio
(Constant)		−43.9		12.4		−40.9	
Design and construction	Stance length	0.0 (0.0)	1.0	0.0[b] (0.0)	1.0	0.0 (0.0)	1.0
	Superstructure (timber, roofing)	−2.0 (1.8)	0.1	−5.0[c] (2.0)	0.01	4.3[c] (2.1)	70.6
	Raised pit	−1.5 (1.2)	0.2	2.1[d] (1.1)	7.9	1.7 (1.4)	5.8
Structural condition of Pit latrine	Sign of pit latrine collapse	0.4 (0.9)	1.5	0.0 (1.1)	1.0	1.9[d] (1.1)	6.4
	Sign of rainstorm water entry	3.5[a] (1.2)	34.6	−0.7 (1.1)	0.5	−0.2 (1.1)	0.9
Operation and maintenance	Flooding area	1.7[d] (0.9)	5.3	1.2 (1.1)	3.3	−2.3[d] (1.2)	0.1
	Private to households only	−0.9 (1.7)	0.4	−4.5[c] (2.2)	0.01	20.9 (3E+04)	1E+09
	Cleaning – every after/before use	1.6[c] (0.7)	5.0	−3.7[b] (1.3)	0.02	1.3 (1.0)	3.6
State and performance of the latrine	Latrine cleanliness	*NA*		4.6[a](1.1)	97.6	1.3 (1.3)	3.8
Notes:	B = regression coefficient SE = standard error R^2 = measure of goodness of model fit determined using the Cox & Snell and Nagelkerke approaches Method = the entry method	Model X^2 (15, N = 108) = 61.4 $P < 0.001$, 81.5 (%predicted) $R^2 = 0.43$ (Cox & Snell), 0.59 (Nagelkerke)		Model X^2 (22, N = 107) = 86.8 $P < 0.001$, 86 (%predicted) $R^2 = 0.56$ (Cox & Snell), 0.75 (Nagelkerke)		Model X^2 (22, N = 107) = 37.6 $p = 0.02$, 90.7 (%predicted) $R^2 = 0.30$ (Cox & Snell), 0.51 (Nagelkerke)	
		Levels of significance: [a]$p < 0.001$, [b]$p < 0.01$, [c]$p < 0.05$, [d]$p < 0.1$					

Addition of waste streams other than human excreta in pit latrines was minimal in this study. Studies have reported presence of household rubbish/garbage in pit latrine content (Banks, 2014; Buckley et al., 2008). The minimal disposal of other wastes in pit latrines could be due to the users being conscious of high filling rates of their latrines. Further, while disposal of sanitary wastes like baby diapers and menstrual pads in pit latrines was mentioned, earlier studies have shown that menstrual hygiene in slum is mainly by re-usable material owing to the expenses involved in buying pads (Kwiringira, Atekyereza, Niwagaba, & Günther, 2014b). Therefore, other factors rather than external waste streams account for the poor performance of pit latrines in the studied slums.

4.2. Relating status of pit latrines to their performance

Logistic regression indicated a relationship between the status and performance variables of pit latrines in this study. Signs of rain or storm water entry, flooding and cleaning time were significant predictors of pit latrine filling. This is consistent with the findings in modelling pit filling by Todman et al. (2014) where it was noted that the flow and accumulation of water in the latrine has an important effect on the filling rate. Prevention of rain and storm water entry can be addressed in pit latrine construction through raising the slab to at least 150 mm above the ground and providing a roof on the latrine (Franceys et al., 1992; Wagner & Lanoix, 1958). However, in flooding areas, it will be necessary to raise the slab to a level above the highest flood level. The high level of pit content in flooding areas was probably because the pits were small and shallow. In high water table areas, lining of large volume pits is expensive while digging deep pits is hindered by the ground water table. Further, entry of groundwater into the pits cannot be ruled out. While raised pit latrines were reportedly fully lined, research has shown that the contamination of shallow aquifers in slum areas of Kampala is attributed to wastewater infiltration from pit latrines (Nyenje, Foppen, Kulabako, Muwanga, & Uhlenbrook, 2013; Nyenje, Havik, Foppen, Muwanga, & Kulabako, 2014). Therefore, pit latrines are either not fully lined or they leak. Additionally the cleaning before/after use by a high user number implies an increase of water input into the pit.

The predictors of smell found in this study were cleanliness, stance length, superstructure material, use by households only and cleaning after/before use of the latrine. Studies directly relating smell to cleanliness are limited. However, smell has always been proxy for dirty toilets. Household use of latrines and cleaning before or after use could result in cleaner latrines that smell less. Sonego and Mosler (2014) found habitual cleaning behaviour to be the strongest predictor of latrine cleanliness.

The length of the latrine stance as a predictor of smell could be

Table 7
Logistic regression predictors of level of pit content.

	Performance indicators		
	Level of pit content	Smell	Fly presence
Model Chi-square	X^2 (1, N = 38) = 12.14, $p < 0.001$	X^2 (2, N = 38) = 24.803 $p < 0.001$	Initial -2log likelihood = 15.67
R^2 (Nagelkerke),	0.37	0.65	–
%predicted	73.7	84.2	94.7
Significant predictors	***Variables in equation***		
	Households using the pit latrine *B(SE)* = 0.435(0.16)[b] Odds Ratio = 1.55	Raised pit *B(SE)* = 3.311(1.16)[b] Odds Ratio = 27.4 Latrine cleanliness *B(SE)* = 2.97(1.17)[c] Odds Ratio = 19.46	Constant only
	Variables not in equation (all significant at p = 0.1)		
	Flooding area Rain or storm water entry	Flooding area	Raised pit Superstructure material Cleanliness

Notes: [a]$p < 0.001$, [b]$p < 0.01$, [c]$p < 0.05$, [d]$p < 0.1$; B = regression coefficient; SE = standard error method – Forward Stepwise (Likelihood Ratio) method.

linked to an increase in volume/size of the pit latrine structure, which decreases the air exchange rate. Superstructures made out of timber/roofing sheets on the other hand, have a higher airflow rates. According to Mara (1984), at high air exchange rates, odours are less likely to accumulate within the superstructure. Additionally the air exchange rate increases directly with ventilation rates, but decreases inversely with superstructure size.

Flies presence was related to superstructure material. Superstructures made out of timber/roofing sheets have more light within the superstructure unlike brick structures. As flies are phototropic (Irish et al., 2013; Wagner & Lanoix, 1958) they will go into the timber/roofing sheet structures.

Interestingly, while the improved designs performed better than the traditional pit latrine, the VIP did not provide superior performance (smell, flies) to the simple pit latrine. Additionally, VIPs were not likely to smell less and have fewer flies than simple pit latrines because they were not meeting the minimum design standards (Tables 2 and 3). This finding is similar to the findings by Dumpert (2008) who noted inadequate VIP design as a hindrance to their proper functioning. The shortfalls in the VIP design could be attributed to limited knowledge of the users about pit latrine designs. Secondly, overcrowding in the slums could impede ventilation within the VIPs to achieve odourless conditions. Variations in predictors of performance were observed at individual slum level. This could be due to variations in characteristics between slums.

5. Conclusions

The design of pit latrines in Kampala's slums was characteristically similar, but there were variations in the construction and operation/usage and maintenance of the latrines. Further, the performance (filling, smell and insects' nuisance) of pit latrines was inadequate. Interventions to improve the performance of pit latrines should tackle their design and operation. Specific considerations should focus on minimising water inflows into the pit, increasing the air flow rate, minimising light in the superstructures and ensuring cleanliness of the latrines. Additionally, determining and ensuring adaptation of appropriate pit latrine standards is important. The findings from this research provide important information for slum settlements, which are known to have varying characteristics and is very informative for local policy makers, practitioners, researchers and donor agencies. It provides a basis for design modifications and recommendations for pit latrine use in slums.

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