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TRANSFORMATION TOWARDS SUSTAINABLE
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Pit latrine faecal sludge accumulation: assessment of trends and determinants in low-income settlements, Nakuru, Kenya

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Sustainable pit latrine services face numerous challenges despite their sanitation role in non-sewerage connected settlements. This study was carried in 5 low income settlements in Nakuru, Kenya. Its objectives were to assess pit latrine user management and sludge accumulation rates. 100 households were surveyed and fill-up in 73 pit latrines monitored. Operational period average was 15 years, 23 people shared a pit latrine, 61% of the facilities had solid waste disposal and 45% of the respondents had no sanitation awareness. Sludge accumulation ranged from -0.98 to 10.32 m^3, fill up rate was 0.87±0.20 m^3 per year and individual contribution was 41.82 liters annually. The sludge accumulation rates across the study areas had statistically significant mean difference (Fishers Exact Test, $p<0.05$). The relationship between user activities, operational management and design affect performance. Hence linking the variables would scale up outcomes. Key words: Faecal sludge, shared sanitation, latrine fill-up, basic sanitation.

Introduction

Efficient sanitation service has a fundamental role in improving people's health, economic wellbeing, dignity, and protection of the local environment (Bartram et al., 2005). Adequate sanitation can support good health hence acting as an intervention to disease outbreaks (Barreto et al., 2007). Proper disposal of human excreta has more significance than the provision of safe water since it significantly lowers the possibility of faecal contamination of environmental resources (Bartram & Cairncross, 2010).

Globally, 2.4 billion people do not have access to improved sanitation services (WHO/UNICEF, 2015). Open defecation is still being practiced by almost one billion people; hence the need to address sanitation needs (Hutton and Bartram, 2008). According to JMP 2015, the least developed countries did not meet the sanitation targets with only 27% of their current populations gaining access to improved sanitation. If SDGs are to be achieved then sanitation policies and programs must be directed towards the marginalized and under-privileged populations with a focus not only on hardware provision but also on information and awareness (Hutton & Chase, 2016; Simiyu et al., 2017).

Access to improved sanitation facilities in Kenya from 1990 to 2015 have increased from 25% to 30%. In Kenya, approximately 60% of the urban dwellers live in peri-urban low-income settlements characterized by inadequate water supply and sanitation facilities. This population is not served by functional sewerage systems; it utilizes on-site facilities (Norris, 2000). Similar statistics has been reported in most developing countries. Pit latrines are used widely, but they pose management and operational constraints (Osumanu, 2008). The sanitation provision task does not end at the point of pit latrine construction.

The unpredictable nature of operational management of the pit latrines pose economic and environmental sanitation constraint to users, property owners and the government. They do not provide services when full. Theoretically, stabilization or content leaching should be equal to the sludge accumulation rates (Buckley et al., 2008). There is limited attention in the form of research and development, hence the study contributes to informed policy making, structural design and operational aspects of pit latrine improvement. This study

adopted a time series survey of user practices and fill-up rates to determine the relationship between management activities and sludge accumulation rates of unlined pit latrines.

Methods

Study area

Nakuru is the fourth largest urban centre in Kenya with a population of about 307 990 inhabitants (GoK, 2009). Three of the study areas were within the peri-urban low-income settlements of Nakuru Sub-County (Kaptembwo, Free Area and Hilton) while two others were located in Njoro Sub-County (Jewadhu and Njokerio). The major economic activities of the inhabitants are in the informal sector with irregular sources of income. Nakuru Sub-county is located at an altitude of between 1810- 1950m and experience a bimodal mild climate. Temperatures range between 17-25^{0}C, while the average annual rainfall is 1000 mm. Whereas Njoro Sub-County They lie at an altitude between 2157- 2286 m. The region experience mild bimodal climate and rainfall range between 760 -1270 mm annually. All the study areas were within the same geographical location hence it was assumed that they share similar soil types.

Data collection

The study was carried out between December 2014 and September 2015. A cross sectional design was applied to provide insight into the design and management practices. Questionnaires were administered to household heads and an observation schedule was executed at every visit to the facility by during monthly fill up measurements. On the other hand, the longitudinal study approach was used to monitor changes in the pit volume for 10 months. Data collections using the two study designs are illustrated in Photograph 1.

Photograph 1: Survey of users and monitoring monthly fill up measurement of pit latrines

Pit latrines included in the study were selected purposefully based on the following exclusion criteria.

- Unlined pit latrines
- Dry pit content: pit latrines without connection to water sources
- Pit latrines serving more than one household daily
- Pit latrines with contents not more than one metre from the drop hole level
- Pit latrines which had not been emptied since construction.

However, 23 pit latrines could not be monitored to the end of the study due decommissioning by owners, emptying, reengineering and social misconceptions by property owners.

The pit latrine fill-up rates were measured using a digital laser range finder (Bosch PLR 25, Bosch GmbH) with a level fixed to previously determined points within the latrine. In addition, tape measures and spirit levels were used for taking physical dimensions of the pit latrine vaults. The total volume of the vaults was

measured at the beginning of the study, followed by bi-monthly measurement of volume changes for a period of 10 months. The formulae below show the methods to fill-up determination:

1. **Accumulation**= (Initial vault volume-final vault volume)
2. *The sludge accumulation rate was calculated based on the average sludge accumulation against the total months for monitoring the study
3. **Daily fill up rates**= (accumulation ÷days monitored) L
4. **Accumulation per person per day (l/p/d)** = (daily fill up rates ÷ number of users)
5. **Annual accumulation rates** = (Fill up rates ×365 days) L
6. **Accumulation per person per year (l/p/yr)** = (l/p/d ×365 days) L.

Results

Sharing of pit latrines and operational management

All the pit latrines were shared by more than 1 family with the largest proportion of pit latrines (47%) being shared by 5-15 families, 17% more than 45 families, 31% less than 5 families, 2% shared by 16-25 and 35-45 families and 1% shared by 26-35 families. The number of people sharing a pit latrine ranged between 4 and 56 people with an average 23 individuals. Disposal of wastes into the vault and on the slab showed that 61% of the pit latrines contained other solid wastes apart from the faecal sludge. The household survey showed that 45% of the residents have not had any awareness of the importance and maintenance of sanitation provision. The largest proportion of hygiene services is offered by families at 51% and the least proportion offered by workers at 2%. Owners (6%), random cleaning (15%) and voluntary cleaning (26%), provided the other cleaning service provisions.

Pit latrine sludge accumulation rates

Sludge accumulation ranged from -98 to 10320 litres and mean accumulation for all the pit latrines was 870 litres. Fill up rates differed across the latrines with some recording accumulation increase while others had volume decreases. However, there were no significant variations across seasons. Accumulation varied significantly across the study locations with Kaptembwo having highest and Njokerio recording the lowest accumulation ($p<0.05$) as illustrated in Figure 2.

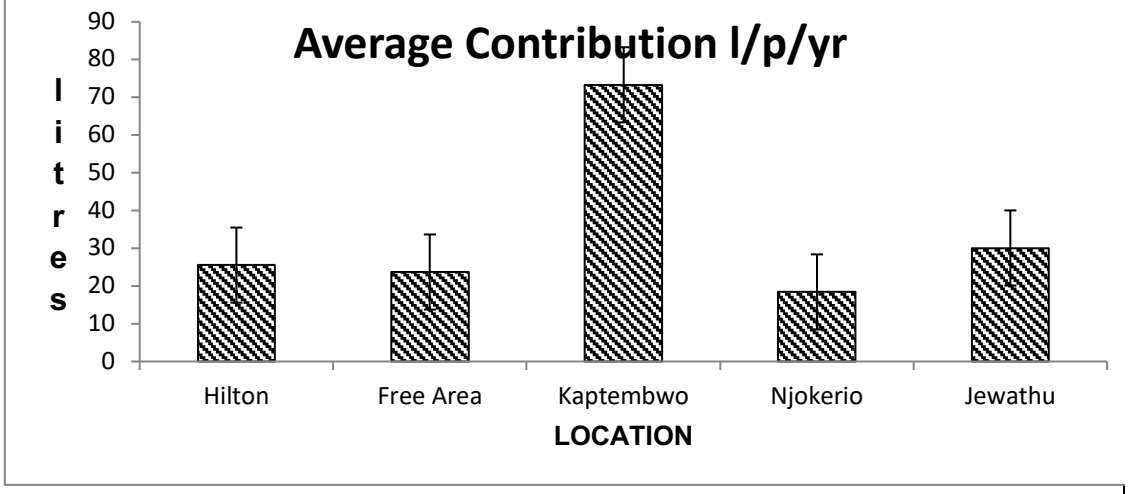

Figure 2. Location Average Accumulation Per Pit Latrine

The accumulation contribution per person ranged from 11.69 to 135.51 litres per person per year, with a mean of 41.82 litres per person annually (l/p/yr).

Table 1. Pit latrine fill up rates and annual sludge contribution per person

Fill-up Rates (m^3/yr)				Individual (l/p/yr)		
Location	Mean ±SD	Min	Max	Mean ±SD	Min	Max
Hilton	0.78± 0.91	0.12	3.01	47.26±7.84	11.69	100.96
Free area	0.59±0.50	0.01	1.49	34.10±20.94	16.62	75.39
Kaptembwa	2.16± 2.71	0.06	10.32	51.00±41.10	14.70	147.2
Jewadhu	0.24±0.59	-0.76	1.54	31.30±14.70	14.8	59.51
Njokerio	0.01± 0.64	-0.98	1.37	47.26±24.79	21.93	101.36

Cross evaluation of the fill up rates among individual pit latrines showed statistically significant differences in volume changes across all the study units ($F(4, 69, 0.05) = 4.54$ with p- value 0.002). Mean comparison of the volume changes of the pit latrines at varying locations showed statistically significant difference between pit latrines in Kaptembwo and those in all the other locations (Fisher's Exact Test). Kaptembwo showed the highest rate of solid waste (70.83%) and grey water (50%) disposal into the pit latrines. Therefore, the variations in user activities as documented by the survey justify the differences in fill up rates of pit latrine within and across the study locations.

Discussion

Defining acceptable pit latrine standards and operational management would provide significant impetus towards achieving the SDGs goals on sanitation and meeting the JMP standards (Simiyu 2017). All the sampled units had no features and characteristics of improved pit latrines recommended by JMP (WHO/UNICEF, 2015). Design failure to factor post fill up management is a major feature observed in many developing countries as also reported in Kampala (Katukiza et al., 2010). The designs do not factor social, cultural, behavioral and gender aspects of sanitation facilities, hence destined to fail. Sharing facilities puts pressure on facility use, limit basic hygiene maintenance and lowers dignity of users. Shared facilities play a significant sanitation delivery role but there is need for better approaches that link hardware and information.

The average number of people sharing a latrine was 23. It is higher compared to those reported in Kampala as 10 people (Tumwine et al., 2003). However, it is lower compared to those reported in Kibera, Kenya as 150 people per pit latrine according to UN-World Bank report in 1997. Sharing a latrine has profound implications for the dignity and privacy of facility users. It could also influence people to resort to open defecation especially when there are long queues during peak periods of facility use (early morning and night). Waste disposal and absence of awareness negates planning of operational management during use and post fill up.

The mean sludge accumulation rates of 41.84 l/p/yr were relatively moderate compared to the WHO recommendation of 40 to 60 l/p/yr and up to 90 l/p/yr where dry cleansing materials are used. The accumulation was within the range reported by WHO in the 1950s indicating a mean annual fill up of 40 litres in dry pit latrines characterized by solid materials and other waste disposals (Wagner and Lanoix, 1958). However, they are lower than data from Brazil and Besters camp South Africa that documented an average of 90 and 69.4 l/p/yr (Franceys et al., 1992; Bhagwan et al., 2008). On the contrary, studies in South Africa reported relatively lower accumulation rates of 24 l/p/yr, but indicated a 50% increase in cases where solid wastes are thrown into the vault (Norris, 2000).

Limitations of the study

Future studies need to evaluate variations in soil types around individual pit latrines, ground water flow, ground water table, soil permeability and aspects of micro environmental parameters that may affect seepage within vaults.

Conclusion

There are variations in user activities, management practices and sludge accumulation rates. The area that had the highest individual contribution of sludge had the highest documented sharing and waste disposal into the pit latrines. All the pit latrines did not factor minimal standards of improved facilities. Equally, management during use was rudimentary and largely unplanned. Shared facilities play a significant sanitation role in low income settlements, therefore, the WHO should consider the blanket condemnation of such facilities. In this area, a pit latrine of 2.5 m^3 would serve five people for 12 years. Therefore, property owners and construction artisans need to understand applicable and standard pit latrine structural designs in peri-urban settlements. In as much as the user practices determine fill up rates of pit latrines, the link between information (awareness and training) and structural designs (vault size, supper structure, slab materials, emptying provision & compartments) may result in significant improvement in pit latrine performance.

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