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# Pit latrine faecal sludge solid waste quantification and characterization to inform the design of treatment facilities in peri-urban areas: A case study of Kanyama

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**The purpose of the study was to quantify waste content in faecal sludge using an appropriate method and characterise the solid wastes inherent with the faecal sludge into categories. A total of eight (8) domestic pit-latrines were analysed in the peri-urban area of Kanyama settlement in Lusaka from July to October, 2018. From each latrine, three (3) samples were obtained for analysis of solid waste and sand/grit quantities. The quantified solid waste was further characterised to generate its composition. The method of estimation involved separation of the excreta from the solid waste and grit/sand of the faecal sludge by means of washing and drying of the contents. The results indicated high content of total waste, taken as the summation of all the solid waste including grit/sand which averaged 34.2±10.3% (n=24) per wet mass of faecal sludge and 68.9±8.0% (n=24) per dry mass of faecal sludge. Characterisation of the solid waste in the faecal sludge (n=24) showed a composition of 54.4±13.3% textiles, 16.7±6.4% plastics, 8.6±9.3% others, 8.6±5.8% organic waste, 7.6±4.8% paper, 3.1±3.6% metal and 1.0±1.2% glass. The high content of waste has an implication on the handling of faecal sludge especially at the stages of desludging, treatment and disposal/re-use. The study proposed and recommended implementation of user education, improving solid waste management systems in peri-urban areas and studying the feasibility of placing some facilities like biogas digesters above ground to facilitate removal of grit, which is usually problematic with underground facilities. The study also proposed and recommended strengthening the regulation on the construction and operations of latrines, which should be supported by enacting a responsive regulatory framework to ensure all measures, are effectively implemented.**

**Key words:** Faecal sludge, peri-urban area, pit latrine, solid waste management.

## INTRODUCTION

Strande et al. (2014) reports that between 65 and 100% of the urban population in most Sub-Sahara African countries access sanitation exclusively through onsite systems. Of the onsite facilities used, pit latrines are the most prevalent especially in low cost areas of large cities (Jenkins et al., 2015; Templeton et al., 2015; WHO/UNICEF, 2014; Thye et al., 2011). This is because pit latrines are the cheapest means of excreta disposal and provide the most inexpensive means of improving sanitation coverage especially in developing countries (Graham and Polizzotto, 2013). Worldwide, it has been acknowledged that one of the biggest shortcomings of pit-latrines is their finite capacity which leads them to fill up within a few months or years of usage (Murungi and van Dijk, 2014; Still and O'Riordan, 2012; Still et al., 2005). Management of the full latrine is through either burying or replacement with a new one or if it is desired to continue using the same latrine, it can then be emptied and put back into service (Jenkins et al., 2015; Still and O'Riordan, 2012; Pickford and Shaw, 1997). The option of burying works well in areas where there is sufficient space that allows for digging of new replacement latrines when the old ones fill up. For Peri-Urban Areas (PUAs) in large cities, pit emptying is a more practical option since most of these areas are normally faced with lack of space (Akumuntu et al., 2017). In addition to space constraints, high costs associated with the construction of a decent new latrine superstructure make emptying a more attractive option (O'Riordan, 2009; Muller and Rijnsburger, 1994).

Emptying a single pit latrine can cause a serious health hazard if not properly handled Mwale, 2013, as the freshly deposited sludge at the top of the latrine contain pathogenic microorganisms, hence the need for Faecal Sludge Management (FSM) systems. FSM is the process of managing faecal sludge from onsite sanitation facilities like pit latrines and septic tanks at all stages of the sanitation service chain which includes storage, desludging, transportation, treatment, disposal and/or re-use (Strande et al., 2014). This means, appropriate means of faecal sludge containment, desludging, treatment and disposal or re-use need to be sought. In addition, there is need for an enabling environment especially as it relates to faecal sludge and solid waste management regulation.

Torondel (2010) defines faecal sludge as a mixture of human excreta, water and solid wastes that are disposed of in the pits, tanks or vaults of onsite sanitation systems such as anal cleansing materials, menstrual hygiene materials, diapers, plastics, paper. Some of these materials like plastics are non-biodegradable. Other non-biodegradable materials are deliberately disposed of in pit latrines. For PUAs in Lusaka, which are defined as "Areas within the jurisdiction of the local authority, having high population density and low cost housing units lacking basic services such as water supply, roads and sewerage (MLGH, 2014; NWASCO/ DTF, 2005), Tembo et al., (2016), contend that one of the reasons for the disposal of solid waste in pit latrines is the absence of functional solid waste management systems in these areas which leaves residents with no other option of solid waste disposal. Regardless of the source, solid waste usually poses a challenge in processing of faecal sludge. The diversity of this material influences the decomposition process that occurs in the pit latrines. The accumulation of these solid wastes can be significant, causing problems with desludging and resulting in clogged pipes and pumps within the treatment facilities. The solid waste also takes up space in reactors effectively reducing reactor retention times and consequently affecting the quality of the treatment products (Strande et al., 2014). Strande et al. (2014) further submit that grit/sand concentrations are also important to consider in the treatment of faecal sludge as their presence influence the required size of treatment facilities. This is because grit affects the filling rates of treatment facilities and can increase the frequency of clogging in pipes and pumps.

Lusaka, the capital city of Zambia has about 70% of its population residing in PUAs (MLGH, 2014). According to SMEC (2016), about 90% of people residing in PUAs use unimproved pit latrines. This is indicative of the need for an effective FSM system in the city. In recent years, Zambia's FSM, landscape, has been improving fast with the advent of the Lusaka Sanitation Programme (LSP), which is a five year initiative by the Lusaka Water and Sewerage Company (LWSC). This initiative partly seeks to improve onsite sanitation and FSM in Lusaka City. This has led to development of strategies for enhanced provision of onsite sanitation and FSM services. For instance, in 2018, the framework for provision of urban onsite sanitation and FSM was launched to assist with the creation of a regulatory framework for onsite sanitation and FSM that supports the proper functioning of an integrated management system covering the whole sanitation chain (NWASCO, 2018). However, solid waste management has not received the same attention and has therefore continued to lag behind. In his study, Sibanda (2010) indicated that the existing regulatory framework for solid waste management in Zambia was comprehensive but enforcement was weak. He also submitted that most people in Zambia are not

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**ABBREVIATIONS: CBD**: Central business district; **FSM**: Faecal sludge management; **LWSC**: Lusaka water and sewerage company limited; **PUAs**: Peri-urban areas.

environmentally conscious, which promotes indiscriminate waste disposal.

Generally, implementation of an effective FSM system requires availability of quality and quantity data on the faecal sludge to be managed to aid in the design of facilities (Strande et al., 2014; Bassan et al., 2013). Data on quantities of solid waste is also cardinal in the design of FSM facilities. Worldwide, it has been acknowledged that solid waste content in the faecal sludge heavily impacts on the performance of the FSM especially at desludging, treatment and disposal/re-use stages. In the FSM being piloted in Lusaka under LWSC in Zambia, mechanical desludging of faecal sludge is impossible due to high content of solid waste. This has resulted in the use of modified garden tools as a means of desludging (Mikhael and Drabble, 2014).

Strande et al. (2018) submit that governments and other stakeholders have started to acknowledge the importance of FSM. However, they observe that efforts to enhance FSM predominantly focus on FSM infrastructure development. The required studies on quantities and qualities of faecal sludge are usually rare despite the fact that this is critical requirement in the design of adequate faecal sludge treatment facilities (Fanyin-Martin et al., 2017). With this status on the availability of the general faecal sludge quantity and quality, specific data on the relative quantities and characteristics of the solid waste contained in pit latrine faecal sludge are even more obscure. This means that the design of appropriate faecal sludge treatment facilities becomes a challenge because of lack of exact data of physiognomies and quantities of the solid waste present in the pit latrines (Mwale, 2013). Secondly, accepted methodologies for representative characterisation and quantification of the solid waste in pit latrine faecal sludge do not exist. In line with aforementioned, the purpose of this study was therefore to come up with a suitable method to employ in the generation of the quantities and characteristics of solid waste found in domestic pit latrines in PUAs of Lusaka using Kanyama as a study area. The study ultimately designed a suitable method and quantified and characterized the solid waste inherent with pit latrine faecal sludge. The generated data will inform the appropriate designs of FSM facilities to adequately address challenges associated with the presence of solid waste and grit in faecal sludge.

## METHODOLOGY

### Overview

The study sought to design a method for and quantifying solid waste and grit in pit latrine faecal sludge. A quantitative methodology utilizing experimental methods was therefore employed. The main steps taken in ensuring successful execution of the study included, selecting the study area, designing a sampling frame, selecting pit latrines to be sampled, sample collection, determination of the content of various constituents of waste in the sludge and data analysis as detailed in the ensuing sections.

In this study, solid waste in the faecal sludge was put in two categories; as either grit/sand; and other forms of solid waste including plastics, glass, textiles (sacks, rugs, sanitary pads and diapers), paper, metals, organic waste (including vegetation matter like grass and logs) and others. Therefore, in the rest of the paper, solid waste will refer to the inorganic constituents found in pit latrines excluding grit/sand, which is also considered separately.

### Study area

The study area, Kanyama settlement, is an improvement area, which was legalized in 1999 by the Ministry of Local Government under the statutory and improvement areas act of 1999. The settlement is located 7 km west of the Central Business District (CBD). It is bordered by Los Angeles and Mumbwa roads on the western and eastern sides respectively (Figure 1). The settlement covers an estimated area of 14.25 $km^2$. According to the Central Statistics Office (CSO), the 2010 population density of Kanyama was approximately 5,636 people/ $km^2$ (Brinkhoff, 2018). The population is estimated at 366,170 (CSO, 2010) with 78, 995 informal housing units that rely on onsite sanitation facilities for excreta disposal (Nyambe, et al., 2014). Most of the residents live in rented multi-roomed dwellings that accommodate more than one family. Its proximity to the city's CBD is responsible for its big size and high population density as most of its residents are primarily migrants from the rural areas coming to seek employment opportunities in the city especially the CBD. Access to adequate sanitation and the existence of service like solid waste collection is very poor in the settlement. The low access to sanitation facilities, unavailability of an effective FSM system, a porous geology as the area is sited on dolomite and a high water table perpetuates outbreaks of water borne diseases such as cholera and typhoid. During the 2017/2018 cholera outbreak in the city of Lusaka, Kanyama PUA alone accounted for over 1,000 cholera cases (WHO/MoH, 2018), making it one of the worst affected areas in the country.

Selection of Kanyama settlement as a study area was dictated by availability of an FSM enterprise in the area. In the study area, Kanyama Water Trust offers faecal sludge desludging services. Since samples were collected as the pit latrines were being desludged (as detailed under sample collection), it was imperative that the study area be an area where formal pit latrine desludging services were available hence the selection of Kanyama Settlement.

### Sampling frame and selection of pit latrines to be sampled

The sampling frame for this study included all households within the study area utilising pit latrines for disposal of excreta. Selection of pits to be sampled was random. As it was only possible to collect samples as the pit latrines were being desludged, the pits sampled were not pre-selected. Rather, they were selected by virtue of them having been earmarked for desludging by the desludging enterprise. A total of eight (08) pits were sampled for this purpose.

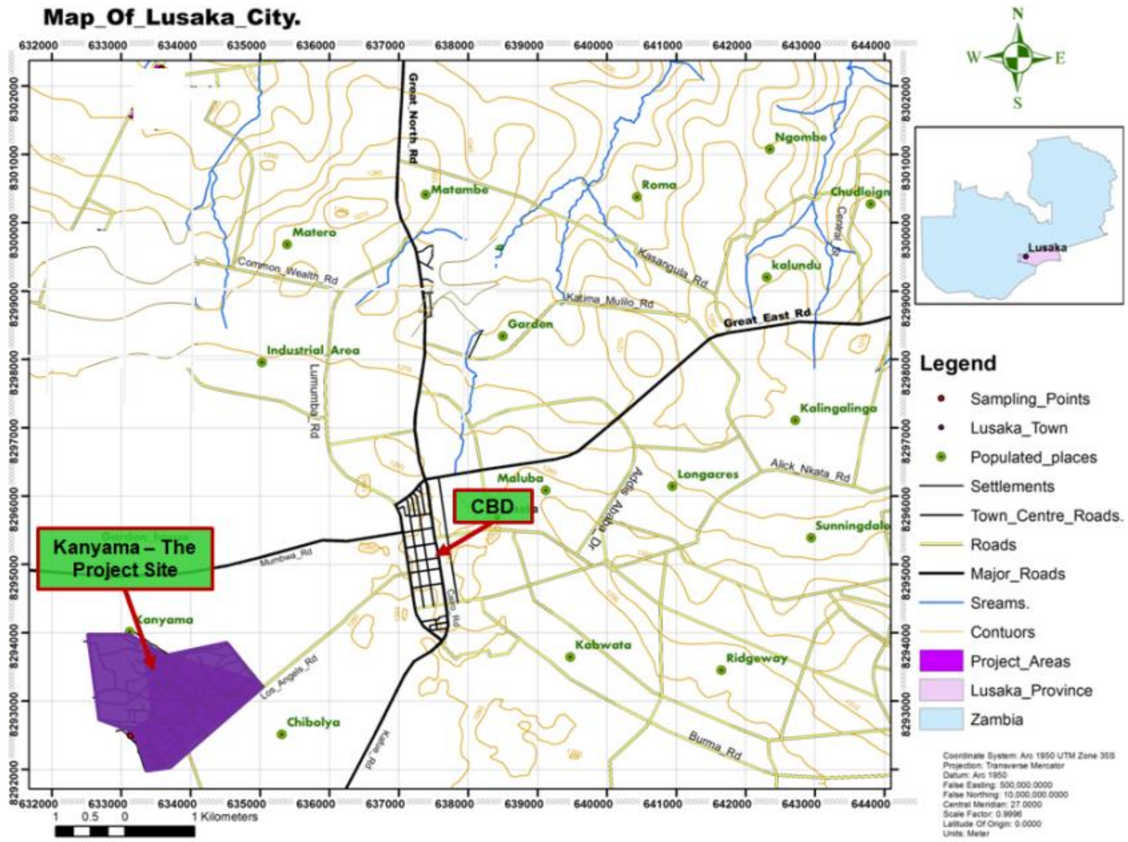


**Figure 1.** Location Map of the Kanyama study area in Lusaka, capital city of Zambia.

### Equipment and materials

The study required the collection of samples from pit latrines which were consequently to be separated through washing into the various constituents which were then dried and weighed to determine the composition of the various components as required. Equipment and materials employed in the study are presented subsequently.

#### *At desludging stage*

Desludging tools included shovels, picks and modified tools for scooping of sludge, disinfectants for cleaning the desludging tools and sanitising the area after desludging 60 L barrels for collection of samples and 250 mL plastic containers for collection of samples for laboratory determination of moisture content.

#### *At the separation stage*

Scales for weighing of sludge and the respective constituents; a hosepipe to aid with the washing of the sludge in the separation process, a source of water and a polythene sheet for storage of separated waste components.

#### *At the stage of laboratory moisture content determination*

Crucibles; a laboratory scales for weighing samples for moisture content determination; an oven with a provision for temperature setting at 103°C to 105°C; and a desiccator.

### Sample collection

All samples were collected from pit latrines that were being desludged by the Water trust. Sampling was conducted from July to October, 2018 which was during the dry season. Prior to the desludging process, an assessment on the structural integrity of the structure was first carried out by the Kanyama water trust personnel. After certification that the structure was sound enough, a hole measuring approximately 30 to 50 cm was made on the side to provide access to the pit latrine contents. This process involved removal of a few blocks from the side of the latrine's vault to create access. The faecal sludge was then scooped out using modified garden tools and a 'Kanjote', which is a tin attached to a long metallic handle (Figure 2).

The sampling was designed based on the number of barrels that were to be desludged. The desludging team offered three options for desludging as follows (Holm et al., 2015): 12 barrels of 60 L capacity; 24 barrels of 60 L capacity; and 32 barrels of 60 L


**Figure 2.** Sample collection: Left: A hole made on the side of the latrines; Middle: Some of the desludging tools including a modified garden rake and a 'Kanjote'; Right: Filling the barrel in the Kanyama study area.

**Table 1.** Barrels to be collected for waste content analysis depending on the number of barrels being desludged.

| Number of barrels to be desludged | Number of barrels collected per pit | Sequencing of barrels collected for analysis |
|---|---|---|
| 12 | 3 | $4^{th}$, $8^{th}$ and $12^{th}$ |
| 24 | 3 | $4^{th}$, $14^{th}$ and $24^{th}$ |
| 32 | 3 | $4^{th}$, $18^{th}$ and $32^{nd}$ |

Source: Designed by author.

**Figure 3.** Faecal sludge sampling for analysis (Left: Collection of three 60 liter barrels per Pit latrine; Right: Three samples collected from each barrel for Moisture Content analysis).

capacity. Depending on the number of barrels being desludged, a sampling criterion was devised for the selection of barrels to be collected for analysis as presented in Table 1. The rationale for this criterion was in order to have representative samples covering the full depth profile of the pits.

Therefore, from each pit that was being emptied, three 60 L barrels were collected. The selected barrels were properly labelled and were later transported to the Kanyama faecal sludge treatment plant where separation of the grit, solid waste and excreta components of the faecal sludge was done. From each of the three barrels earmarked for quantification and characterization, three smaller samples were collected for analysis of moisture content (Figure 3). This moisture content was intended to help in the approximation of the dry excreta component of the faecal sludge. The collection of these samples was therefore done in a way that avoided collection of solid waste and grit as far as it was possible.

### Procedure for laboratory moisture content analysis

The laboratory analysis of moisture content for all the collected samples was carried out at University of Zambia Environmental

**Figure 4.** Weighing of the barrel together with the faecal sludge before separation, Kanyama study area.


**Figure 5.** Washing of faecal sludge to separate the sludge from grit and solid waste, Kanyama study area.

Engineering Laboratory. The analysis was done in accordance with the standard protocols specified in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998).

**Procedure for quantification of the solid waste and grit**

The quantification started with the weighing of the faecal sludge contained in the barrels (Figure 4). This was done by weighing the total mass of barrel filled with sludge, which was recorded as mass (A). The mass of the dry barrel was also recorded after all the contents had been removed, which was recorded as (B).

***Separation of the excreta component of the faecal sludge from the grit and solid waste***

Separation of the excreta component of the faecal sludge from the rest of the contents (that is, grit and solid waste) was done using water. In order to reduce on chances of washing out the solid waste and grit due to agitations as the water was flowing out, the contents of the barrel were first divided into two portions to create enough room for expansion of the FS bed during washing. Each portion was then washed separately and gently using a hosepipe in each respective barrel. The washing continued until all the excreta component was washed off from the sand/grit and the solid waste. This separation was facilitated by the differences in densities, the agitation and continued injection of water into the barrels. The overflowing water, which carried with it the excreta component of the faecal sludge was channelled into the anaerobic digester (Figure 5).

***Quantification of the solid waste and grit***

During the washing of the faecal sludge, the solid waste was manually separated from the contents. After all the excreta had been washed off, the remaining solid waste that could not be separated during washing was manually sorted out from the grit. The solid waste was then thoroughly air dried for two days. The dried waste was then weighed and the mass was recorded (Mass C).

Total Mass of Sludge = A – B

Total Mass of Dry Solid Waste = C

Solid Waste Content (D as % of wet sludge) = (C/(A-B)) x 100 (1)

After the thorough washing and removal of all the solid waste, the grit that remained was also air dried for two days as was the case for the solid waste. The air dried grit was then weighed in the field and the mass was recorded (Mass E). As the drying of grit was not thorough, samples were then collected from the air dried grit for moisture content analysis in the laboratory. The mass of the dried grit was then computed as in the Equation 2.

Mass or air dried grit = E
Moisture content of air dried grit = X%

Mass of dried grit (F) = (E x (1-X/100)) (2)

The grit content in the wet sludge expressed as a percent was then computed using Equation 3.

Grit content (G as % of wet sludge) = (F/(A-B)) x 100 (3)

Both solid waste and grit content in the dry faecal sludge was computed by expressing the masses of the computed dry solid waste and grit as a percentage of the total mass of dry faecal sludge. The total dry mass was computed by summing up the masses of the dried solid waste, the dried grit and the dry mass of excreta, which was approximated by multiplying the mass of the excreta component of the faecal sludge by the solids content percentage. Thus, the excreta component of the dry faecal sludge was computed as per Equation 4.

Mass of dry excreta component of FS = ((A-B)-(C+F))* (1-MC/100) (4)

where, MC is the moisture content of the faecal sludge.

***Characterisation of the solid waste***

After the solid waste was quantified as explained previously, it was sorted into the following categories: plastics, glass, textiles, paper, metals, organic waste and others (Figure 6). The sorting was done manually. The separated fractions were then weighed and their masses were computed as percentages of the total dry mass of the solid waste.

#### Data analysis

For each pit latrines, mean results were computed from the three sets of results that were obtained for the three samples collected from each latrine. Sample standard deviation was computed to measure the degree of spread of the data. The overall mean for both solid waste and grit was computed by summing up all the individual results. Solid waste characterisation results were manipulated using excel software to generate graphs.

#### Limitations

The major limitation of the study was on the inflexibility of sampling. It was not possible to pre-select the latrines to be sampled as the study team had to follow the program for desludging as designed by the water trust. Secondly, it would have been ideal to have samples collected over the whole pit latrine depth profile. However, this was not possible as all latrines that were sampled were only partially desludged. The study was also limited to the dry season (July to October) implying that impacts of seasonal variations on the results could not be assessed.

## RESULTS

The results are herein presented.

### Moisture content

As presented in the methodology section, moisture content in this study was analysed to aid the conversion of the excreta and grit components to their respective dry masses. The mean moisture content in the faecal sludge and the air dried grit from respective pit latrines is presented in Table 2.

The results of the mean moisture content of the faecal sludge and the air dried grit (n=24) were found to be 81.1±6.4% and 26.0±5.8%, respectively.

### Solid waste content

The solid waste content ranged between 3.4±2.3% and 34.6±8.5% (n=3) in wet sludge and was between 12.0±7.8% and 54.5±2.9% (n=3) in dry sludge. The means were 17.6±10.4% and 31.1±13.5% in wet and dry sludge, respectively (Table 3).

### Grit content

Grit content ranged between 12.6±3.2% and 22.6±4.8% (n=3) in wet sludge and 23.3±5.2% and 58.0±2.7% (n=3) in dry sludge. The averages were 17.3±6.7 and 33.9±13.3% (n=24) in the wet and dry sludge, respectively (Table 4).

### Total waste content in faecal sludge

The total waste content in the sludge, which was a summation of the solid waste and grit/sand content in each of the respective sampled latrines presented ranges of 20.9% to 54.2% and 58.5% to 84.6% (n=3) in wet and dry faecal sludge respectively. The computed averages were 34.2±10.3% in wet sludge and 68.9±8.0% (n=24) in dry sludge (Table 5).

**Figure 6.** Examples of some constituents from the fractionated solid waste (Left: Plastics; Middle: organic waste; Right: Textiles (note the high content of diapers within the textile component), Kanyama study area.

**Table 2.** Mean moisture content results in the FS and the air dried grit from respective pit latrines, Kanyama study area.

| Pit ID | Moisture Content in the FS (%) | Moisture Content in the Air Dried Sand (%) | Number of Samples (n) |
|---|---|---|---|
| PIT 01 | 74.5±4.2 | 24.9±3.8 | 3 |
| PIT 02 | 84.9±5.5 | 25.3±6.7 | 3 |
| PIT 03 | 84.5±2.0 | 25.9±3.3 | 3 |
| PIT 04 | 88.2±2.8 | 24.9±1.8 | 3 |
| PIT 05 | 80.4±2.4 | 23.7±2.2 | 3 |
| PIT 06 | 72.9±1.1 | 33.5±1.4 | 3 |
| PIT 07 | 81.8±3.6 | 25.8±7.6 | 3 |
| PIT 08 | 81.0±3.1 | 23.4±4.8 | 3 |
| Mean (%) | 81.1±6.4 | 26.0±5.8 | 24 |

Source: Compiled by author.

**Table 3.** Solid waste composition content in faecal sludge from Kanyama Study area.

| Pit ID | Composition of solid waste in FS (As % of wet mass) | Composition of solid waste in FS (As % of dry mass) | Number of Samples (n) |
|---|---|---|---|
| PIT 01 | 14.4±1.6 | 27.6±1.3 | 3 |
| PIT 02 | 18.9±6.3 | 39.8±3.1 | 3 |
| PIT 03 | 15±4.6 | 36.6±3.45 | 3 |
| PIT 04 | 3.41±2.3 | 12.0±7.8 | 3 |
| PIT 05 | 34.6±8.5 | 54.5±2.9 | 3 |
| PIT 06 | 25.1±11.0 | 44.6±14.0 | 3 |
| PIT 07 | 10.4±9.4 | 25.0±16.8 | 3 |
| PIT 08 | 13.3±6.3 | 29.9±13.9 | 3 |
| Mean (%) | 17.6±10.4 | 31.1±13.5 | 24 |

Source: Compiled by author.

## Solid waste characterization

Solid waste characterisation showed a general trend across all the surveyed pits with textiles registering the highest values and glass and metals registering the least (Table 6).

On average textiles registered the highest composition at 54.4±13.3% (n = 24) with glass registering the least at

**Table 4.** Sand content in faecal sludge from Kanyama study area.

| Pit ID | Composition of grit in FS (As % of wet mass) | Composition of grit in FS (As % of dry mass) | Number of Samples (n) |
|---|---|---|---|
| PIT 01 | 22.6±4.84 | 30.9±2.9 | 3 |
| PIT 02 | 18.7±6.7 | 28.2±4.5 | 3 |
| PIT 03 | 16.3± 13.8 | 34.8±16.0 | 3 |
| PIT 04 | 17.5±2.9 | 58.0±2.7 | 3 |
| PIT 05 | 19.6±6.4 | 30.1±4.8 | 3 |
| PIT 06 | 12.6±3.2 | 23.3±5.8 | 3 |
| PIT 07 | 12.7±2.9 | 35.2±5.4 | 3 |
| PIT 08 | 18.7±7.3 | 40.9±11.6 | 3 |
| Mean (%) | 17.3±6.7 | 33.9±13.3 | 24 |

Source: Compiled by author.

**Table 5.** Total waste content (grit plus solid waste) in the faecal sludge from Kanyama study area.

| Pit ID | Content of total waste (% in wet sludge) | Content of total waste (% in dry sludge) | Number of Samples (n) |
|---|---|---|---|
| PIT 01 | 37 | 58.5 | 3 |
| PIT 02 | 37.6 | 68.0 | 3 |
| PIT 03 | 31.3 | 71.4 | 3 |
| PIT 04 | 20.9 | 70 | 3 |
| PIT 05 | 54.2 | 84.6 | 3 |
| PIT 06 | 37.7 | 67.9 | 3 |
| PIT 07 | 23.1 | 60.2 | 3 |
| PIT 08 | 32 | 70.8 | 3 |
| Mean (%) | 34.2±10.3 | 68.9±8.0 | 24 |

Source: Compiled by author.

**Table 6**. Characterised solid wastes across pit latrines from Kanyama study area.

| Category | Pit Identification | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PIT 01 | PIT 02 | PIT 03 | PIT 04 | PIT 05 | PIT 06 | PIT 07 | PIT 08 |
| Plastics | 8.9±1.1 | 7.1±4.5 | 12.5±4.1 | 21.7±22.2 | 18.1±5.8 | 23.5±9.9 | 22.1±7.8 | 20.0±5.9 |
| Glass | 0.7±1.2 | 3.0±3.1 | 0.8±1.5 | 0.0±0.00 | 2.7±4.7 | 0.0±0.0 | 0.0±0.0 | 0.5±0.9 |
| Textiles | 28.7±10.7 | 50.4±7.2 | 55.9±9.4 | 68.4±11.5 | 71.8±9.7 | 60.1±22.2 | 49.9±16.1 | 50.3±9.1 |
| Paper | 6.9±4.3 | 5.5±2.9 | 8.9±3.3 | 5.4±5.6 | 1.5±0.6 | 4.2±1.2 | 11.4±8.5 | 16.9±6.1 |
| Metals | 6.8±6.2 | 7.3±12.7 | 7.4±8.3 | 0.0±0.0 | 0.0±0.0 | 0.0±0.0 | 3.4±5.7 | 0.0±0.0 |
| Organic waste | 20.6±12.9 | 10.4±11.0 | 4.9±2.6 | 4.6±5.8 | 2.7±1.4 | 5.6±7.6 | 8.1±10.5 | 12.0±10.9 |
| Others | 27.4±6.5 | 16.4±11.1 | 9.7±5.0 | 0±0.0 | 3.2±1.4 | 6.6±6.6 | 5.1±8.8 | 0.2±0.4 |
| No. of Samples (n) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

Source: Compiled by author

1.0±1.2% (n=24). The contents varied significantly across pit latrines as evident from the huge standard deviation

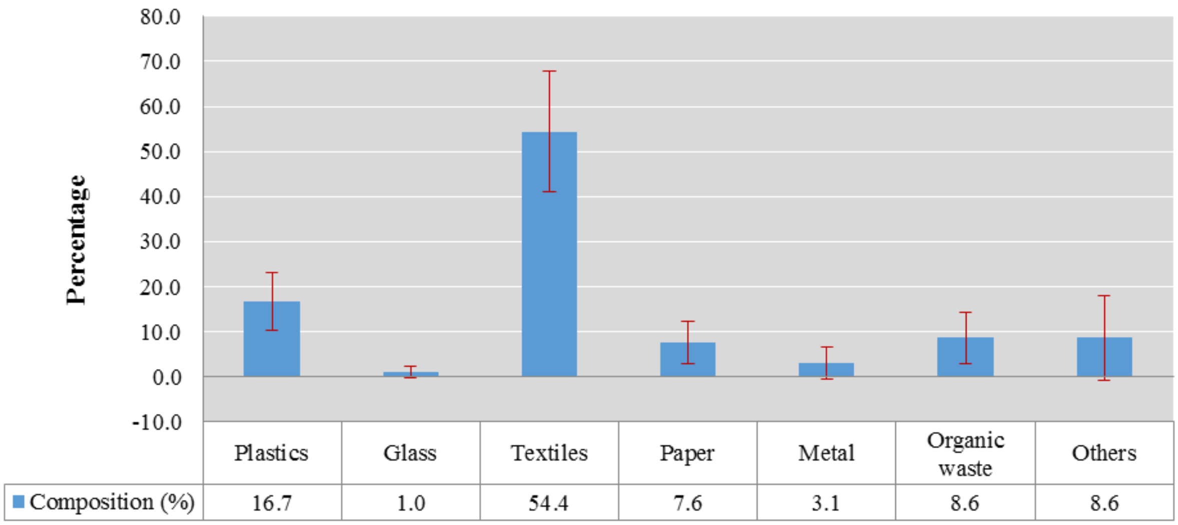


**Figure 7.** Solid waste characterization results with standard deviations for each category from Kanyama study area.

values especially for glass and metals (Figure 7).

## DISCUSSION

The study set out to formulate a method to generate reliable data on quantities of waste in faecal sludge from pit latrines in PUAs using Kanyama settlement as a case study area. Generally, results showed higher contents of both solid waste and grit. Solid waste averaged 17.6±10.4% (n=24) in wet sludge. This result closely agrees with the findings by Parker et al. (2015) of 12% using a similar method as the one used in this study. The mean content in dry mass of the faecal sludge was almost at 34 percent (n=24). The observed high content of waste can be attributed to the socio-cultural perceptions and the socioeconomic setup of PUAs. Culturally, there is stigma attached to menstruation in most of the Zambian cultures where pads and materials used during menstruation have to be disposed of in a manner that ensures maximum secrecy. Secondly, the introduction of diapers to replace napkins has also exacerbated the situation. Although diapers can be disposed of together with the other forms of solid waste, in PUAs, they also end up in pit latrines and is one of the biggest contributor to textile component as is evident in Figure 6 above. Solid waste disposal in pit latrines is also a result of unavailability of functional solid waste management systems in these areas (Tembo et. al., 2016).

The observed high content of grit results from a number of sanitation practices, which include construction and usage of pit latrines. Some latrines in the study area are constructed with large squatting holes beyond the 25 cm recommended by WHO (1996) making them dangerous for young children. Others are just not accessible to children due to the way they are constructed (Figure 8).

Following from these inadequacies in construction, children are allowed to defeacate on the ground within the household premises after which the excreta is picked and deposited into the latrine. A shovel or hoe is usually used to pick the excreta. When the excreta is picked, an appreciable amount of soil is also collected and this ends up in the latrine. Grit also comes from the unlined portions of the latrines (Tembo et al., 2016). However, the majority of the grit ending up in the emptied sludge was observed to have been from the desludging method used. Desludging was observed to be a “two-stage” scooping system. The sludge was first scooped from the pit using modified garden tools into a temporary pit that was dug to receive the sludge from the pit. The sludge was then scooped from the temporary pit into the barrels (Figure 2). As the temporally pit was unlined with a lot of loose sand, it was a source of most of the grit.

High contents of both solid waste and grit content complicates treatment processes especially if adequate units are not put in place to address the challenges inherent with the waste. High content of solid waste leads to system blockages, which result in high frequency of reactor maintenance. This requires putting the reactor out of service for some time hence disrupting the treatment process. This was observed for the two pilot plants managed for LWSC by the water trusts in Kanyama and Chazanga. At re-use stage, high solid waste content also

**Figure 8.** Example of latrine construction and interfaces that discourage direct latrine usage by young children from Kanyama study area.

poses challenges. For example, in the valorisation of faecal sludge to generate power, demineralised water and ash using an Omni processor, grit serious hampers the processes. For sludge with grit content in excess of 5 percent of the dry mass, the Omni processor's operations are impaired (Malo, 2017, Dakar, Senegal, personal communication). This implies that with the current grit content in desludged sludge, the Omni processor technology is not an option for the pit latrine faecal sludge from PUAs. Non-biodegradable waste like rags and plastics, which were found to be present in large quantities in this study is an aspect that compromises the ultimate re-use of the sludge in agricultural activities. When present in form of sharp objects, solid waste may also pose health and safety risks especially to workers handling the sludge (IWMI, 2003).

From the foregoing, it is evident that the high content of waste in pit latrine faecal sludge is an aspect that culminates from number of aspects including social-cultural, lack of understanding on the part of residents, absence of adequate solid waste management systems and the construction and operation aspects of the latrines, which result in introduction of waste. For grit, the adopted means of desludging, which is due to the unregulated construction exaggerates the amounts. The latrines are constructed without any provision for desludging. Non availability of standards for construction of pit latrines results in construction of facilities that are not user friendly especially to children resulting in practices that introduce grit into the pit contents. Grit content is exacerbated by the adopted method of desludging, which is due to inappropriate construction of latrines. High solid waste content in the sludge due to indiscriminate disposal of waste into the latrines was another problem that was observed. All these challenges point to the need for regulation of latrine construction, awareness creation and usage to enhance the desludging and treatment of the sludge. It is imperative at design stage to adequately take cognisance of the high content of solid waste in pit latrine faecal sludge to have units that are adequately designed to address the challenges inherent with the observed quality of the pit latrines faecal sludge as well as to create awareness among the users of the facilities.

## CONCLUSION AND RECOMMENDATIONS

The study aimed at coming up with a method for the estimation and characterisation of solid waste and grit in pit latrine faecal sludge. This was achieved. The developed method was gravimetric making its application universal. The obtained results indicated high content of both solid waste and grit with textiles contributing the highest percentage for the solid waste content. From these results, it is evident that these high values of waste have implications on the method of desludging employed as well as on the treatment efficiencies and effectiveness of plants and the ultimate disposal/re-use of the faecal sludge. The limitations imposed on the study arising from the inflexibility of sampling and the inability to sample the full depth profile of the pit latrines as highlighted in the limitations section do not result in significant impacts on the results as these are not variables that have a bearing on the content of solid waste. However, quantities of both grit and solid waste may vary with seasons as in partially lined pit latrines, moisture content is likely to increase in the rainy season thereby reducing the solids content of the excreta component.

Based on the findings, it was clear that the latrines in PUAs do not only serve as excreta disposal facilities, but also as receptors of solid waste. If the management of the faecal sludge from these facilities is to be improved measures for reducing high waste in faecal sludge need to be implemented. These include: implementation of user education in PUAs as a way of averting challenges inherent with solid waste disposal; operationalizing alternative solid waste management systems in PUAs so that the collection and disposal of the waste in these areas is improved; and to regulate the construction of latrines so that all facilities are constructed with easy means of desludging to avoid desludging methods that increase sand/grit content in the sludge that ends up at the treatment plant. It would also be important to investigate the feasibility of building some of the critical facilities in the treatment of faecal sludge, like biogas digesters, above ground for easy removal of accumulated grit and solid waste, which is usually a challenge when the unit is underground as is usually the case with biogas digesters. Ultimately, there is need for a responsive regulatory framework to ensure that all measures are effectively implemented.

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## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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