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FRACTIONAL CONTENT OF NON-FEACAL MATTER AND ITS CONTRIBUTION TO FILLING RATES OF PIT LATRINES IN KAMPALA SLUMS

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ABSTRACT
In densely populated low income cities, hygiene and sanitation problems emanating from poor wastewater management remain a challenge. Therefore, the objective of this paper was to examine the composition of non-feacal matter in pit latrines and its contribution to their filling rates in Kampala slums. Thirty (30) rental pit latrines were purposively selected from slum areas in Kawempe and Rubaga divisions and samples were collected prior to and after pit emptying. Non feacal matter was sorted at the pit latrine and at the disposal point before weighing. Results revealed no significant difference ($P > 0.05$) in pit volumes, an average volume of 1.09 m3 was recorded. The study revealed a fractional content of non-feacal matter of 25.8 1.7% (mean □ SEM). Results revealed that non-feacal matter composition is inversely related to pit volume. A weak negative correlation was established between pit volume and non-feacal matter composition. There is need to model the impact of non-feacal matter on pit latrine filling rates. Sensitization of pit latrine users about adverse impacts of dumping non-biodegradable solid waste in pit latrines should be done. Research efforts aimed at designing a pit latrine with drop hole that can trap solid waste entry should be explored.

INTRODUCTION
Kampala city hosts the largest part of urban population in Uganda with a day-time population of about 2.9 million people and estimated to grow at 5.1% per year (UBOS, 2014). The high rates of urbanization and population growth rate coupled with ever increasing cost of living has forced many people into lower income settlements and as such there is a high expansion of urban slums (Günther *et al*., 2011). A slum in Uganda's context and as used in this paper is a heavily populated urban area characterized by substandard houses, social and economic isolation, irregular land ownership, low standards of sanitation, limited access to basic infrastructure and poor social services (Avuni, 2011). In addition, the challenges of slums are further compounded by poor accessibility and lack of legal status making it difficult to improve their level of sanitation. In the slums pit latrines have been widely adopted and are used due to their simplicity and low cost with regard to construction, operation and maintenance (Nakagiri *et al*., 2015). Within the slum settlements the congestion and unplanned sanitation systems make feacal sludge and solid waste management and disposal costly and sometimes infeasible since residences are inaccessible (Thye *et al*., 2009; Katukiza *et al*., 2010; Semiyaga *et al*., 2015). Pit emptying is always an enormous challenge in slum areas (Murungi and van Dijk, 2014), especially because in slum areas there is virtually no space to dispose of pit contents on site (DWAF, 2007; Nwaneri, 2009). Besides, most pit latrines in Kampala slums are inappropriately designed and built (Norris, 2000). It is not surprising that access to improved sanitation in urban slums of developing countries is still very low (Cotton *et al*., 1995). The problem is compounded by the limited connectivity to water and planned sewer systems whereby a large majority of urban slum dwellers rely on pit latrines and open garbage disposal points as their basic sanitation facilities (Niwagaba, 2008; SRFA, 2013; Nakagiri *et al*., 2015). With limited water supply use of water flushed toilets becomes impossible moreover in some cases the pit latrines are shared and as would be expected in a slum, not properly maintained in hygienic conditions (Günther, *et al*., 2012). It should be noted that achieving and maintaining hygienic toilets shared by several user households in urban slums is usually a challenge (Tumwebaze *et al*., 2014) because most of the users do not usually want to take the responsibility of cleaning especially in circumstances where the facility is shared by multiple households.

Usually the same pit latrines are also used for disposal of other non-biodegradable solid wastes, a phenomenon that lowers the service life of the pits and undermines effective management of community hygiene. Often times due to the limited space and lack of alternatives, the same shared pit latrines are used as disposal points for other solid waste such as sanitary pads, dippers, plastics and garbage (Niwagaba, 2009; SRFA, 2013). The heavy deposition of non-biodegradable material in pit latrines meant for fecal sludge tends to disrupt the natural decomposition dynamics inside the latrine and the continuous pilling of solid leads to high pit filling rates (Broukaert *et al*., 2013). The quick filling up of latrines used for both feacal matter and solids deposition is exacerbated in shallow, lined and raised pit latrines (Figure 1) such as those that are constructed in swampy areas (Herzog, 2007). In addition, there is a challenge of adoption of the gravity flow pit emptying technique involving release of feacal sludge into nearby waste water channels to address the rapid filling rates in shallow pit latrines (Figure 2). Katukiza *et al*., (2012) noted that poor sanitation in urban slums results in increased prevalence of diseases and pollution of the environment and identified solid wastes as the major contributors to the pollution load. This undesirable situation usually leads to frequent preventable disease outbreaks in most congested slums particularly during the rainy season which is usually evidence of poor sanitation (Montgomery, 2007; Kulabako *et al*., 2010).

Figure 1: Raised pit latrine with a ladder to ease access

Figure 2: A raised pit latrine with an outlet

Apart from early fill up of the pit latrine, deposition of non-large biodegradable solids also makes the pit emptying very difficult. According to Wood (2013), during mechanical pit emptying, non-feacal materials in the pit clog the suction pipes making it difficult to empty the pit contents and this leaves manual emptying, with its shortcomings, the only viable option (Kone and Chowdhry, 2012). Other challenges caused by non-fecal solid waste disposal in pit latrines include the need for bigger storage and treatment volumes and disposal of residual non-feacal matter at treatment plants (Figure 2) after screening through the feacal sludge. In order to improve sustainability of safe feacal disposal and improved community sanitation based on pit latrine models in congested slum settlements, there is need to understand and quantify the composition of non-feacal material deposited in pit latrines. However, limited information is available on the nature and extent of non-feacal matter deposition in pit latrines and its impact on pit-latrine filling rates in urban slums. It should be noted that variation in household habits and local environmental conditions contributes to differences in non-biodegradable content between different pits (Bakare *et al*., 2012). The author noted that determination of the composition of the material present in any particular pit latrine requires total removal and observation of the content because of its complex nature particularly in slum areas where pits are used for both sanitation needs and dumping of household solid waste including non-biodegradable newspapers, magazines, broken glasses, bottles, rags and plastic bags (Figure 3). To bridge this gap, this study investigated the fractional composition of non-biodegradable non-feacal matter and in pit-latrine content and its contribution to filling rates of lined pit latrines in Kampala slums. The research focused on public lined pit latrines, which are prone to the practice of disposing-off solid waste, particularly those found in rental housing units and are used by multiple families, usually tenants and are characterized by poor management due to recklessness of pit users.

Figure 3: Non-feacal material collected by screens at treatment plant

METHODS

Description of the Study Area

The study was conducted in the slum settlements of Rubaga and Kawempe divisions located in Kampala district, central Uganda. Administratively, Kampala district comprises of five divisions namely: Nakawa, Rubaga, Kampala Central, Kawempe and Makindye (Figure 4). The terrain is steep lying at an altitude of about 1300m above sea level, on the north shore of Lake Victoria. With a tropical wet and dry climate and high water table, flooding is frequent and severe a phenomena that contributes to the risk of poor hygiene conditions. The main reason for selection of Kawempe and Rubaga divisions among others is because this part of the city has the highest sanitation challenges in Uganda which is mainly attributed to poor solid waste collection measures, poor pit latrine user behavior and rapid urban population growth rate.

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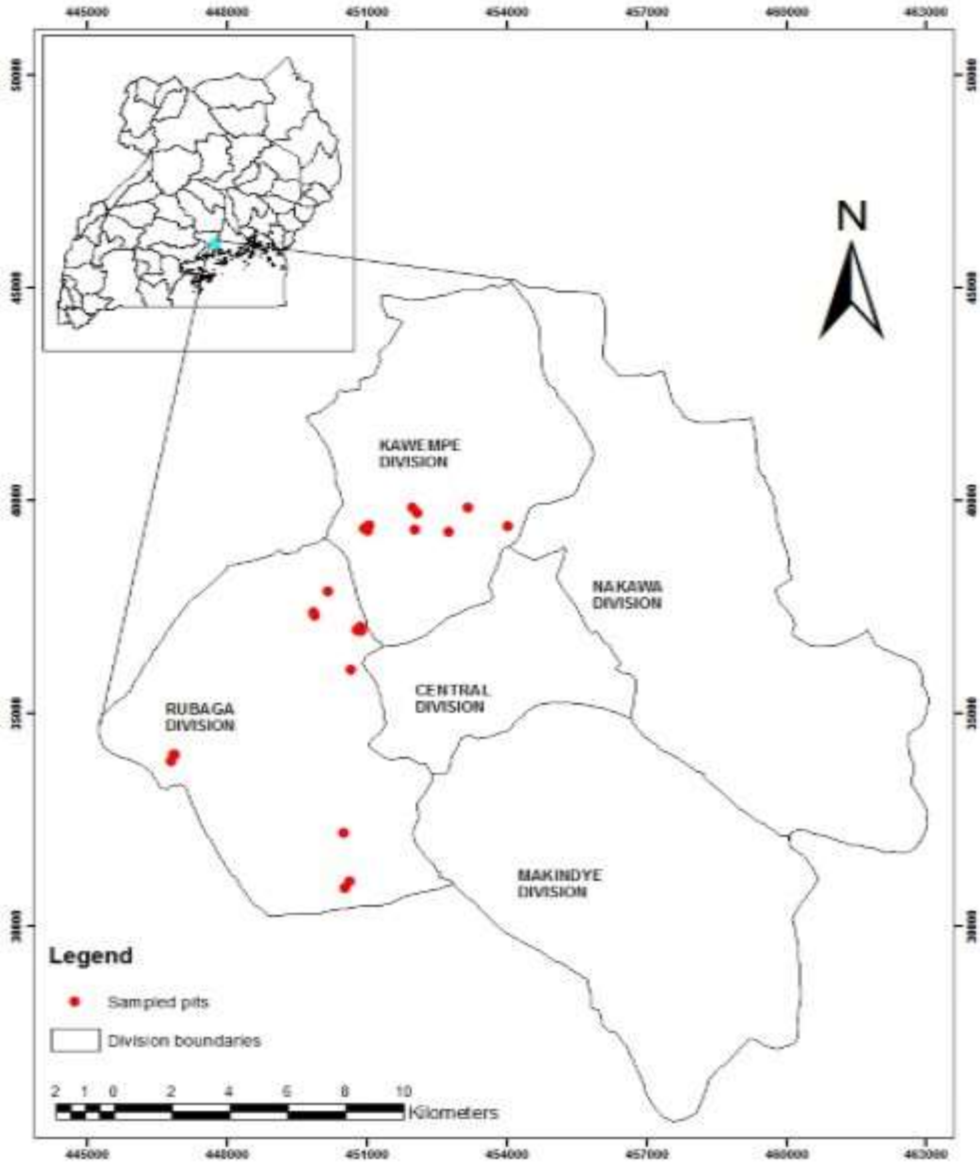

Figure 4: Map of Kampala showing the sampled pit latrines

Sampling

The research was based on field survey involving visiting, identifying, selecting and sampling of pit latrines due for emptying. Data were collected from a sample of thirty (30) purposively selected rental pit latrines from slum areas in Kawempe and Rubaga divisions. The two divisions were selected because they represent the largest proportion of slums in Kampala city. Samples were obtained from three (3) pits within each of the five (5) villages selected from Kawempe and Rubaga divisions (Figure 4) of Kampala district, making a total of 30 samples. Wood (2013) observed variability in pit user behaviour from one community to another and recommended that the sample size in such studies should be more than 30 pit latrines. However, since most of the slums in Kampala suffer from almost similar sanitation challenges according to Kimuli *et al*. (2016), it was assumed that there is limited variability in pit user behaviour among users within the selected sample of thirty almost similar types of pit latrines. Hence, a sample size of 30 pit latrines was considered to give statistically reliable results as this number would adequately capture all the pit latrine users' behaviors in the slums.

Samples were picked in collaboration with pit latrine emptiers who dispose feacal sludge at NWSC Lubigi treatment plant. The samples were collected both from the top surface of full pit latrines and from what (vacuum) pit emptiers had sucked out of the pits during empting of those specific pits. This is because during pit empting, pit contents are exposed which allows separation of both feacal and non-feacal materials for the study. Pit contents were stirred vigorously in order to detach feacal material from non-feacal material hence separating the two after which a rake was carefully used to scoop out the solid non-feacal matter prior to emptying by the trucks. Each emptying truck would then be followed up to the disposal point from where the remaining non-feacal matter was separated using screens. Samples of collected material were initially put in a plastic container to allow for further separation of feacal sludge and solid waste to ensure that only non-feacal matter remains for further analysis as shown in Figure 5. The mass of non-feacal matter on site and at the treatment plant were weighed and recorded as m_1 and m_2, respectively. It is worth noting that the measurements and calculations of non-feacal material did not involve the portion of non-biodegradable solid waste that settles at the bottom of the pit. This is because it is hard to expose them from the pit and it requires breaking the pit latrine unit, which is not feasible. All measurements of non-feacal matter were done on wet basis. The number of pit latrine users was obtained through interviews with landlords and these were confirmed by counting the number of tenements.

Analysis of Fractional Content of Non-Feacal Matter

Pit latrine volume was determined by taking pit dimensions i.e. length and width using a measuring tape. The depth and height of feacal sludge in the pit latrine was also determined using a graduated measuring rod.

Figure 5: Non-feacal matter from pit latrine

Calculation of fractional content by volume of non-feacal matter in pit latrines was preceded by calculation of pit latrine volume using equation (1) below:

$$V_p = l \times w \times d \qquad (1)$$

Where V_p is volume of pit latrine (m^3), d is the height (m) of the pit latrine, l is the length (m) of the pit and w is the width (m) of the pit.

The volume of pit contents was determined by using height of pit contents in the pit before empting. In filled up pits, the volume of pit contents was considered to be equal to the volume of the pit latrine. Uniform distribution of pit contents was assumed hence a rectangular shape was considered.

The total mass of non-feacal matter was obtained by equation (2) below:

$$M_t = m_1 + m_2 \qquad (2)$$

Where M_t is total mass (kg) of non-feacal matter, m_1 is mass of non-feacal matter (kg) obtained on site and m_2 is mass of non-feacal matter (kg) obtained at the treatment plant where all material in the trucks was finally disposed off.

Volume occupied by non-feacal matter in the pit was obtained using equation (3) below:

$$V_n = \frac{M_t}{\rho} \quad (3)$$

Where V_n is volume (m^3) occupied by non-feacal matter in the pit and ρ is uniform density of non-feacal matter (kg/m^3), which was taken as $1300 kg/m^3$, the average density of non-biodegradable solids (such as broken glass, plastics, cotton fabric, wood, etc.) that are commonly deposited in pit latrines as reported by Wood (2013).

The percentage fractional content of non-feacal matter in a pit latrine was obtained by equation (4) below

$$X = \frac{V_n}{V_P} \times 100 \quad (4)$$

Where X is the percentage composition of non-feacal matter and V_p is the volume occupied by removable pit contents.

This study also involved identifying pit emptying approaches used in Kampala slums. The pit emptying approaches used were mainly demand driven where emptying service is done upon request from the pit latrine owners (Murungi and Pieter, 2014) and hence sampling was not done randomly. Full pit latrines, for which owners requested for the empting services, were sampled. The fractional content of non-feacal material found in a pit was considered to represent the extent to which pit latrines are poorly used hence affecting their filling rates. Factors contributing to non-feacal matter disposal in pit latrines were also investigated which included number of pit users and pit volume. Semi structured interviews were also used to obtain feedback on number of pit users for each of the pit latrine of interest. It was hypothesized that the higher the number of pit users the higher the quantity of non-feacal material found in a pit due to lack of regulations on which material should be disposed in the pit. Further still it was assumed that people who dig relatively larger volume pits do it with a multipurpose motive of wanting to dispose both feacal and non-feacal material. Pit latrine dimensions were measured from which the pit volume was calculated and considered as the indicator for pit size.

2.4 Statistical Analysis

The percentage value of non-feacal matter was calculated as a fractional content of the total estimated pit contents and averaged for the number of samples pits. The standard errors show the variations in the mean values. For smaller samples ($n<30$), the statistic t value was read directly from the probability table. This was used in calculating the 95 % confidence interval on the mean value using equation (5) as follows;

$$CI = average \ \pm MOE \quad (5)$$

Where CI is confidence interval, SE is standard error and t is the t-value. Margin of error (MOE) was calculated using equation (6) below:

$$SE = \sigma^2 \big/ \sqrt{N} \quad (6)$$

Where SE is the standard error, σ^2 is the standard deviation and N is the sample size.
Analysis of variance (ANOVA) was used in detecting significant differences between treatments for $p = 0.05$.

RESULTS AND DISCUSSIONS

Pit Latrine Sizes and Volumes

Sampled pit latrines had an average volume of 1.09 m^3 and an average of fourteen (14) users per pit latrine. The observed volume was relatively small compared to the number of pit users. This is because of a high water table in Kampala slums, which is the most prevalent constraint to pit latrine size in the slum areas. The high water table reduces the available depth of the pit hence a small volume is attained. Key informant interviews revealed that majority of private pit latrines were being shared by over five households which is above the number of four recommend by the Uganda's national sanitation guidelines (MOH-Uganda, 2000). This is agreement with Kimuli *et al.* (2016) who observed that in the slum areas, land is subdivided into small plots to an extent of several households sharing pit latrines. This is an indication that pit latrines in urban slums of Kampala city are over loaded. This was in agreement with Isunju *et al.* (2014) who observed that the conditions of some pit latrines in low income areas were insufficient and unhygienic due to the large number of users per stance, which explains the poor sanitation situation in the slum areas of Kampala. One way ANOVA at 95% level of confidence showed

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that there was no significant difference between pit volumes of the sampled pit latrines and this was further evidenced by the fact that observed critical F-value was greater than F-calculated (Table 1). This could be because, all slums suffer from similar constraints i.e. space limitation and ground water level.

Table 1: Analysis of variance for pit latrine volumes in Kampala slums

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.3086	9	0.256517	1.64049	0.170599	2.39288
Within Groups	3.1273	20	0.1564			
Total	5.4359	29				

Pit Latrine Content and composition of non-feacal material

It was observed during sampling that water is well conserved in lined pit latrines and hence it was easy to separate feacal from non-feacal material. As expected there was variation in the types of non-feacal materials extracted from the different pits. Whereas in some pits there were mainly household items such as small jerry cans, plates, cups, flasks, saucepans, spoons, radios, while other pits significantly contained textile materials such as bags, bed sheets, blankets, clothes, shoes and pillows. A small portion of household materials was also found including: polyethene bags, textile materials, condoms, plastic bottles and metallic bottles. Some of the extracted non-feacal materials were characteristic of the material used by the household for anal cleansing (toilet and other paper, water, rags, plastic) and this was in agreement with Still and Foxon (2012). Majority of the non-feacal matter were large size objects that can be trapped by a wire mesh and hence one plausible strategy could be to improve the pit latrine design to incorporate a mesh-like structure just below the stance drop hole to trap any solids that might be dumped in pit latrines by irresponsible users.

Non-feacal matter fractional content

The average percentage composition of non-feacal matter by volume was found out to be 25.8 ± 1.7 (mean ± SEM) at the time of pit emptying, a composition which is in the range of values obtained by Wood (2013). It should however be noted that in some sampled pit latrines, the composition could go as far as 40% non-feacal material, these were considered the extreme situations of irresponsible user behaviour while in places with careful behavior, the composition could go as low as 10% non-feacal matter. The data obtained deviates from the standard mean by 4.6% an implication that observed values did not deviate greatly from the standard mean. The established percentage composition of non feacal matter implies that non-feacal matter contributes to a 25.8% reduction in the useful volume and probably service life of pit latrines within slum areas. This concurs with Bakare *et al*. (2012) who observed that the rate at which the pit fills is proportional to the rate at which non-biodegradable material is added to the pit latrine. Thus one of the sustainable ways to reduce pit accumulation rates in slums is to reduce the amount of household solid waste deposition into the pit latrine.

Factors affecting composition of non-feacal material

When factors suspected to be contributing to the fractional content of non-feacal material in pit latrines were investigated, it was discovered that the higher the number of pit latrine users the less the non-biodegradable content in pit latrines (Figure 6a). This contradicts the earlier hypothesis of the study that the higher the number of pit latrine users the higher the quantity of non-feacal material found in a pit. It is clear that with lower number of users there seems to be an increase in the proportion of non-feacal contents and as the number of users exceeds ten (10) the elements of self-policing and user controls take over in pits shared by multiple users and the non feacal matter deposition reduces. The pit users in this study were considered to be family heads on the tenement house because they influence other family members' pit latrine behaviors. This research excluded visitors and other external pit latrine users. The weak negative relationship meant that the higher the number of pit latrine users the lower the quantity of non-feacal materials. This is because to a certain extent the pit latrines used by many users tend to be used more as sanitation structures for easement as opposed to non-feacal matter deposition and because they are more users any little non-feacal matter deposited would be outweighed by the feacal matter from many users and hence a negative relationship. In addition, rental latrines had strict rules from the landlords not to dispose such materials in the toilets. This concurs with the explanations that were given by some key respondents during sampling alluding to the fact that there exist tenancy agreements that stipulate terms and conditions regarding pit latrine use including limiting solid waste disposal. In addition, the minimal disposal of solid wastes in pit latrines for multiple users could also be due to the users being conscious of high filling rates of their latrines particularly those on relatively new premises (Nakagiri *et al*., 2015;).

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Figure 6b on the other hand indicated a weak inverse correlation between pit latrine volume and non feacal matter composition in pit latrines. This implies that as the pit volume increases the percentage composition of non-feacal matter reduces and this just emphasizes the fact that the sole purpose of constructing larger volume pit latrines, from the proprietor's point of view, is mainly for feacal matter deposition rather than solid waste disposal. This also implies that pits used by more people with larger volumes will have smaller filling rates due to limited deposition of non-biodegradable waste. This finding contradicted the earlier assumption of entrepreneurs digging relatively larger volume pits for a multipurpose motive of disposing both feacal and non-feacal material. The weak negative relationship between non-feacal material and pit volume could be explained by the high filling rates in small pit latrines as compared to big pit latrines. It was found out that pit latrine contents depend on other factors but not number of pit users and pit size. Buckley *et al*. (2008) also stated that unless pit contents are dug out, you could not tell which pit latrine contains more non-feacal material. Foxon and Still (2012) from a similar study also found out that number of pit latrine users was not directly proportional to quantity of non-feacal matter deposited in a pit latrine. This is because the bulk of items disposed in pit latrines are probably characteristic for a household and the management style imposed by the landlords or owners, rather than the number of users.

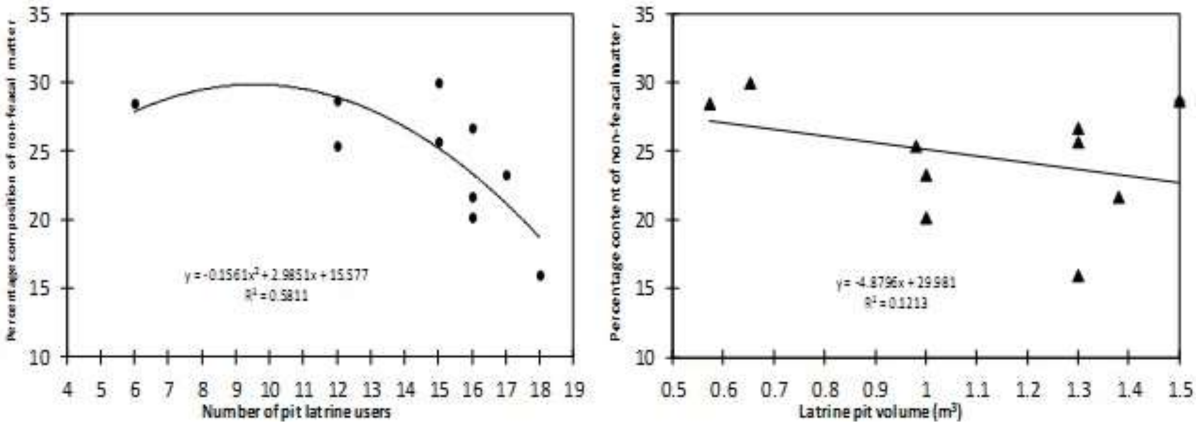

Figure 6: (a) Relationship between number of Pit Latrine Users and Non-Feacal Matter Composition; (b) Relationship between Pit Latrine Volume and Non-Feacal Matter Composition in pits

A fairly good positive correlation was established between number of pit latrine users and pit latrine volume (Figure 7, with the darker data points showing outliers). This coupled with the declining proportion of non-biodegradable content with increasing number of pit latrine users in Figure 5a implies that pits used by more people with larger pit volumes will have smaller filling rates. This is probably due to the growing knowledge by owners of the impact of of the higher amount of non feacal matter usually deposited in most pit latrines in slum areas and this could have influenced them to go in for relatively larger pit volumes to accommodate the solid wastes in addition to feacal matter from the many users.

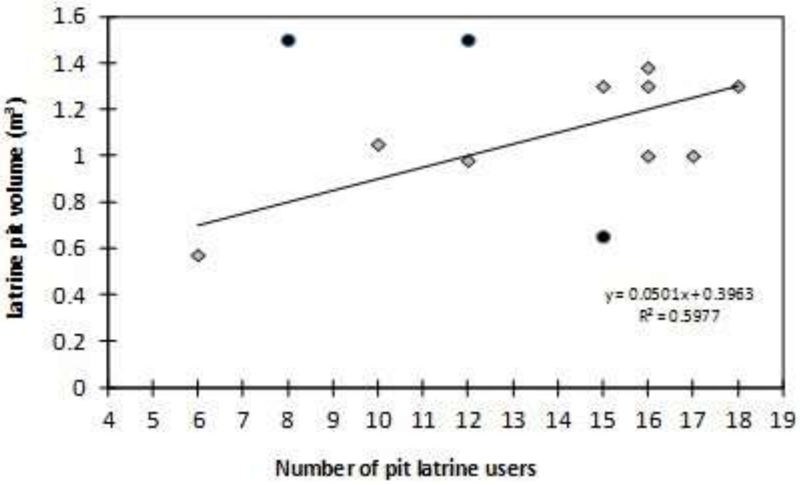

Figure 7: Relationship between number of Pit Latrine Users and Pit Latrine Volume

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this paper was to determine the percentage composition of non-feacal matter in lined pit latrines in slum areas so as to ascertain its impact on pit filling rates and suggest possible solid waste management strategies that could enhance community hygiene. The average fractional content of non-feacal matter in pit latrines was found to be 25.8%. It was concluded that depositing non-feacal matter in pits on average reduces the useful volume in a pit latrine by 25.8%, implying that if non-feacal material is not deposited in pit latrines, the useful volume of pit latrines can be increased. It was also further concluded that composition of non-feacal matter is inversely related to pit latrine volume, so it was confirmed that large volume pit latrines are mainly constructed for feacal deposition rather than doubling as solid waste disposal points in slum areas. It is therefore not correct to assume that large pit latrines are dug in order to collect both feacal and non-feacal matter. It was also concluded that pits used by more people with larger pit volumes will have smaller filling rates due to reduced deposition of un-biodegradable non feacal matter. It was thus recommended that a comparative study of experimentally simulated pits with and without non-feacal matter deposition be conducted to get a clear understanding of the impact of non-feacal matter on pit latrine filling rates. In addition, there is also need for policy makers and urban planners to improve on solid waste collection measures from Kampala slums in order to reduce on deposition of solid waste in pit latrines. In addition, awareness efforts geared at making users understand and appreciate the adverse impacts of dumping non-biodegradable waste into pit latrines on their filling rates should be intensified. More so research and development efforts aimed at modifying the design of the pit latrine drop hole so that it prevents solid waste disposal in pit latrines should be explored.

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