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CIV 4200: CIVIL ENGINEERING PROJECT II
FINAL YEAR PROJECT REPORT;

QUANTIFICATION AND CHARACTERIZATION OF SOLID WASTE IN PIT LATRINES OF URBAN INFORMAL SETTLEMENTS FOR APPROPRIATE MANAGEMENT

BY

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Submitted in Partial Fulfilment of the Requirements for the Award of a Degree of Bachelor of Science in Civil Engineering

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DECLARATION

We hereby declare that the work presented in this report is our original work and has to the best of our knowledge not been submitted to any institution of learning for any award whatsoever.

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DEDICATION

To our parents, supervisors and all those that gave any form of assistance towards our work

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First and foremost, we thank the almighty God for the wisdom, gift of life and perfect health toward the completion of this project work.

We wish to extend our sincerest gratitude to our supervisor Dr. Swaib Semiyaga for the technical input, guidance and his time given during the execution of the project and documentation of this work. We are greatly indebted to you.

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Table of Contents

LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
FS	Faecal Sludge
FSM	Faecal Sludge Management
FST	Faecal Sludge Treatment
HDPE	High Density Polyethene
KCCA	Kampala Capital City Authority
LDPE	Low Density Polyethene
LLDPE	Linear Low Density Polyethene
LWR	Leather Wood and Rubber
MAPET	Manual Pit Emptying Technology
MSW	Municipal Solid Waste
PET	Polyethylene terephthalate
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
UN	United Nations
VIPs	Ventilated Improved Pit latrines

Units and measurements

kg	kilogramme
m	mass
v	volume
ρ	density

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

More than half of the global population lives in urban areas. This figure is projected to increase to 75 percent by 2050, at a growing rate of 65 million urban dwellers annually (Awumbila, 2017). Sub-Saharan Africa (SSA) is often regarded as the world's fastest urbanizing region. Urbanization is accompanied by the growth of informal settlements both in population and size. Informal settlements are characterised by deplorable living conditions, poor sanitation is one of them (Tsinda et al., 2013). These informal settlements remain of high concern as regards sanitation which is one of the targets under Sustainable Development Goals (SDGs).

Kampala is facing a rapid rate of urbanisation which is accompanied by an increase in population and rapid growth in size and number of informal settlements. According to the World Bank collection of development indicators, compiled from officially recognized sources 53.6% of the city's population dwell within informal settlements as of 2014. Therefore, the generation of solid waste by the slum dwellers is considerably high, but the collection services are poor.

A study by Strande, et al., (2014) indicates that between 65% and 100% of the urban dwellers in most Sub-Sahara Africa countries predominantly use onsite sanitation systems (pit latrines and septic tanks). Pit latrines are the most common containment systems for excreta disposal in informal settlements of sub-Saharan Africa due to their low cost of construction and operation as a result of the use of available raw materials for construction and the low level of water services and lack of affordability for waterborne systems (Katukiza et al., 2010).

However, most of these pit latrines are of substandard and contain accumulated faecal sludge (Strande et al., 2018). Therefore, the need for improved onsite sanitation systems particularly Faecal Sludge Management (FSM) facilities in slum areas worldwide is still wanting. It is worth noting that the management of faecal sludge particularly in slum areas is difficult owing to lack of space and resources. This is an appalling situation perceived in many slums worldwide (Yvonne et al., 2016). The noticeable disadvantage of pit latrines is their fixed capacity and therefore fills up within a few month or years necessitating adequate measures. Moreover, a study by Katukiza, et al., (2010) found out that many informal settlements are located in low lying areas characterised by a high water table. As such these pit latrines in slums around Kampala are high rise, therefore, fill up quickly and necessitate frequent emptying. The available options when a pit latrine is full are emptying or abandonment and construction of another one. Due to the lack of space which is characteristic of many slums, pit emptying proves the most viable (Murungi & van Dijk, 2014). Also, many of the slum dwellers are low-income earners therefore the construction of a new pit latrine is nearly impossible (Nakagiri et al., 2015).

Various studies (Tembo, et al., 2019; Gudda, et al., 2019; Nakagiri, et al., 2015) have shown that faecal sludge in informal settlements is independent of solid waste. 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 most of which are non – biodegradable and deliberately disposed in pits. 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 (Tembo, Nyirenda, & Nyambe, 2017). The high content of waste has overly affected the handling of faecal sludge especially at the stages of desludging, treatment and disposal/re-use (James et al., 2019).

1.2 PROBLEM STATEMENT

Pit latrines used in the informal settlements around Kampala city are filling up quickly. (Gudda, et al, 2019). This can be attributed to the volumes of solid waste entering the system ranging from plastic bags, pampers, sanitary pads and condoms to more substantial items like old clothes (Nakagiri et al., 2015). These solid wastes have been reported to have adverse effects on the sanitation systems used by many low-income communities (Gudda, et al., 2019). It has made emptying of filled up latrines using vacuum trucks extremely difficult as pipes get clogged up. It has proved expensive for owners of the latrines in the sense that they have to pay for the removal of garbage before emptying can proceed (Murungi & van Dijk, 2014). Several technologies for example the MAPET and vacutug have been developed to empty faecal sludge mixed with solid wastes, but many have failed to work because the composition of the wastes is not understood. Composition highly differs according to cultures, lifestyles, education levels, among others. Little information is known about the pit latrine solid waste quantities and composition. This information is required if we are to have interventions on preventing solid wastes disposal in pit latrines and also in the development of emptying and treatment technologies.

1.3 STUDY OBJECTIVES

1.3.1Main Objective

The main objective of the study is to determine the quantity and characteristics of non-faecal solid wastes in the pit latrines for a proper understanding of the appropriate technologies for their reduction, emptying and treatment.

1.3.2 Specific Objectives

The specific objectives of the study are;

- To determine the current state of solid waste and faecal sludge management in the two slums.
- To determine the composition of municipal solid waste generated from the two slums.
- To determine the composition of solid waste from the pit latrines.
- To compare solid waste generated from slums with that in pit latrines.

1.4 JUSTIFICATION

There is an increasing need for enhanced Faecal Sludge Management (FSM) in the informal settlements of Kampala city. The design of systems to meet such a need requires data not only on faecal sludge but also solid wastes contained in the sludge since it has been acknowledged worldwide that solid waste affects the performance of FSM systems at the desludging, treatment and disposal/re-use stages.

It is therefore mandatory to research on the quantities and composition of solid wastes within pit latrines of informal settlements around the city. Information on the characteristic of such solid wastes in these containment systems can be vital for laying out strategies for improved management of faecal sludge from the informal settlement as regard treating, emptying and design of faecal sludge containment systems.

1.5 STUDY SCOPE

The study will mainly focus on the quantification and composition of solid wastes in pit latrines in the slum of Makerere III and Kamwokya II.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature on solid wastes and faecal sludge. The different types of pit latrines relevant to the research and their current state of performance are explained. The challenges faced in the usage of pit latrines in peri-urban areas also closely looked at. The literature pertinent to this research is briefly explained in this section.

2.2 Key Definitions

Informal settlements: based on the UN-Habitat Program definition, these are defined as:

i) residential areas where a group of housing units has been constructed on land to which the occupants have no legal claim, or which they occupy illegally;

ii) Unplanned settlements and areas where housing is not in compliance with current planning and building regulations.

These settlements are in general characterized by high occupancy, crowdedness, lack of proper hygiene and sanitation.

Faecal sludge: “Faecal sludge (FS) comes from onsite sanitation technologies, and has not been transported through a sewer. It is raw or partially digested, a slurry or semisolid, and results from the collection, storage or treatment of combinations of excreta and black water, with or without grey water” (Strande, 2014).

Solid waste: “Solid wastes are all the waste arising from human and animal activities that are normally solid and are discarded. It encompasses the heterogeneous mass of throwaways from residential and commercial activities as well as the more homogeneous accumulations of single industrial activities. They are generated by almost every activities and the amount varies by source, season, geography and time” (Corbitt, 2008).

Waste quantification: “ describes the total quantity of waste in a waste stream, by weight or by volume,” (Yu & Maclaren, 1995).

Waste characterization: “the composition of the waste stream, by material types such as glass, paper, metals or by-product types such as glass containers, magazines, cans” (Yu & Maclaren, 1995).

2.3 Solid waste

2.3.1 Municipal solid waste and challenges in Solid waste management.

Municipal solid waste (MSW) is a term often used for the solid heterogeneous by-product of different human activities (Namdeo, Pondhe, & Meshram, 2009). Arguably, majority of the solid waste is generated through human related activities like construction of buildings, hotels and restaurants, institutional activities, slaughter houses and agriculture. The waste generally consists of discarded material like papers, plastic, glass, metal fine earth particles, ash, sewage sludge, dead animals to mention but a few.

Waste management refers to the collection, transport, recovery, and disposal of waste, including the supervision of such operations and after-care of disposal sites. In general waste management is concerned with the existing amount of waste, trying to minimize the human waste or environment waste interface and to minimize potential impact. Waste management should concern itself not only with final disposal of waste but also with the whole cycle of waste creation, transport, storage, treatment, and recovery and does so to minimize pollution (Jerie & Tevera, 2014).

However, solid waste management (SWM) is an in increasingly multidimensional challenge faced by urban authorities, especially in developing countries (Al-Khatib, Monou, Abu Zahra, Shaheen, & Kassinos, 2010). Solid waste collection is currently one of the most wanting public services in slum areas in Uganda and its low coverage has caused public outcry.

The poor management of solid waste contributes to flooding, air pollution, and spreading of diseases and health conditions such as respiratory ailments and diarrhoea, giving rise to severe economic and social losses. As such the surroundings of such communities have become in-habitable. The problems are particularly severe in slums in developing countries where the solid waste management systems are inadequate (Mukama et al., 2016).

In general, the environmentally acceptable management of municipal solid waste has become a global challenge due to limited resources, ever increasing population, rapid urbanization and industrialization worldwide (Pokhrel & Viraraghavan, 2005). According to (Solomon, 2009), some of the common causes for poor waste management services are the lack of appropriate government policy and legislation, lack of political will and public commitment, inadequate technical expertise, insufficient financial resources or inappropriate allocation of available resources, and unavailability of suitable lands for waste disposal sites.

Furthermore, the management of solid waste in peri-urban communicates is complicated by the fact that there is lack of clear understanding of waste generation and its characteristics. This undermines the efforts of municipal authorities to establish and implement efficient solid waste management plans (Al-Khatib et al., 2010). Indeed, due to heterogeneity of the MSW, management of this waste including treatment and its disposal is still a forgotten aspect in many slum areas of developing countries (Namdeo et al., 2009).

2.3.2 Status of solid waste management in urban slums

A study that was carried out by Mukama et al., (2016) indicated that the major categories of waste generated in households were food remains (38%) and plastics (37%). It further revealed that 59.1% of the households stored their wastes in polythene bags, 20.2% in sacks before disposal and 10.3% of the households did not have waste storage containers and kept their wastes outside the house in the open. Also 54.9% of the households that participated in the study reported carrying out some form of waste segregation at the household level. The majority, 78.0% did separate biodegradable wastes, especially food peelings which were mainly collected as animal feed.

According to Mukama et al., (2016) , the common frequencies of waste collection from households were 28.8% weekly and 29.8% biweekly. In addition they reported that 19.6% of the households collected their wastes daily 11.8% fortnightly, 5.3% monthly, and 4.8% rarely collected their solid wastes. Regarding waste disposal, 35.9% disposed of their waste at the dumping site, 24.8% burnt it in open pits, and 25.1% had it collected by trucks. In 76.3% of the households, women were responsible for the waste disposal. In other households, the responsibility of waste disposal was on male adults (11.2%), female children (3.0%), male children (4.4%), and housemaids and relatives (5.1%).

2.3.3 Quantification of solid waste

The quantities of solid waste generated in a community may be estimated by input and output analysis techniques. Input analysis estimates waste based on the use of a number of products by a given person. Output analysis involves the weighing of solid waste with scales . A reliable estimate of the quantity of solid waste generated is very important as regards decision involving the handling of solid waste and its disposal (Yousuf & Rahman, 2007).

The quantities of solid waste are measured in terms of weight and volume (Gawaikar, 2006). The advantage of measuring quantity in terms of weight rather than volume is that weight is fairly constant for a given set of discarded objects, whereas volume is highly variable (Tuprakay, Suksabye, Menchai, & Tuprakay, n.d.).

2.3.4 Characterization of solid waste

An understanding of the present and future characteristics of the waste stream is essential for effective, long-term solid waste management planning (Yu & Maclaren, 1995). The characteristics of a given waste stream are dependent on social structure, income levels, consumption and usage habits of the people (Ozcan, Guvenc, Guvenc, & Demir, 2016). The characteristic of solid waste is a major factor, which is considered as a basis for the design of efficient, cost-effective and environmentally compatible waste management. Therefore, a solid waste management system requires a greater knowledge about composition (Katiyar, Suresh, & Sharma, 2013).

The characteristics and composition of this waste depend upon various factors such as topography of the area, different seasons, food habits, commercial status of the city, etc. Due to heterogeneity in consumption pattern, living standards and income status, the waste products are also of heterogeneous quality and quantity. Solid waste generation and characterization are some of the most important parameters which affect environmental sustainability. Municipal solid waste (MSW) characterization depends on social structure and income levels (Namdeo et al., 2009). An efficient system for MSW management requires a good knowledge of the characterization of solid wastes to be disposed.

2.3.5 Properties of solid waste

The physical and chemical characteristics of a given waste stream are indicators of the quality of the waste contained within that particular stream. The management of solid waste is dependent on both the characteristics of the site and the characteristics of the solid waste itself. Characteristics of solid waste include; gross composition, moisture content, particle size, chemical composition, and density. Physical features of solid wastes are significant parameters for the selection and functioning of collection and transportation equipment, energy transformation, studies related to recoverable matter, as well as selection and design of proper disposal methods. The physical properties of solid waste considered in this study are discussed below;

2.3.5.1 Composition

Composition of waste is determined by various factors which include population, level of income, sources, social behaviour, climate, industrial production and the market for waste materials. This variability makes defining and measuring the composition of waste more difficult and at the same time more essential (Gidarakos, Havas, & Ntzamilis, 2006). The composition is one of the most important characteristics affecting solid waste disposal, or the recovery of materials and energy from refuse (Weiner & Mathews, 2003).

Materials in solid wastes can be broadly categorized into three groups, Compostable, Recyclables and Inert. Compostable or organic fraction comprises of food waste, vegetable market wastes and yard waste. Recyclables are comprised of paper, plastic, metal and glass. The fraction of solid wastes which can neither be composted nor recycled into secondary raw materials is called Inert. Inert comprise stones and silt which is characteristic of the unlined pit latrines. The composition of a given solid waste stream is best described by the percentage of its waste fractions (Tuprakay et al., n.d.).

2.3.5.2 Size of waste

The size of solid waste is represented in the centimetre unit of width and length for each waste composition (Tuprakay et al., n.d.). The size of waste describes the particle size distribution within a given waste composition. Particle size distribution is particularly important in refuse processing for resource recovery (Weiner & Mathews, 2003).

2.3.5.3 Moisture content

Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total wet weight of the waste. Moisture increases the weight of solid waste.

2.3.5.4 Density

The density of waste is the mass per unit volume (kg/m^3). Knowledge of density of solid waste is very important for the design of all elements of a solid waste management system.

2.4 Solid waste in pit latrines

The content of any particular pit latrine consists of a wide range of materials. It is impossible to ascertain the composition of the material contained in any particular pit without physically observing the contents of the pit or digging it out since many households make use of the pit either for their basic sanitation needs or for both sanitation needs and dumping of household solid refuse. In addition to faecal matter, a large variety of other material such as newspaper, magazines, broken glass, bottles, rags, plastic bags and other household waste materials could be found in pits of South Africa (Bakare, Foxon, Brouckaert, & Buckley, 2012).

A study by (Nakagiri et al., 2015) shows that besides human excreta, sanitary products such as baby diapers and menstrual pads, and anal cleansing material 85% of which were newspapers were deposited in the pits. According to (Still, 2002), pit latrines are to a certain extent also used for the disposal of solid wastes such as rags, cloths, plastic and glass which may contribute between 10% and 20% of the observed sludge accumulation rates. Various studies by researchers on pit latrine filling have also shown that the addition of non-degradable material into the pit and water inflows significantly influenced its filling (Brouckaert, Foxon, & Wood, 2013).

Regardless of the source, solid waste usually poses a huge challenge in the processing of faecal sludge. The diversity of this material also 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 (Strande, 2014).

Besides complicating pit emptying and FS treatment, additional solid waste in pits leads to higher emptying fees. In Kampala, the pit emptying fees are based on the volume of removed materials, presence of solid wastes and the travelling distance between the emptied system and the discharge location. The presence of accumulated solid wastes in a sanitation system results in a 10-50% increment on top of the emptying cost as shown in Table 2-1 below

Table 2-1: cost for pit emptying in Kampala including transportation in 5km radius. Source (Strande, 2014)

Truck Capacity (m^3)	Standard Costs (USD)	Penalty for rubbish (10-50%) (USD)	Range of total costs including a rubbish fine (10-50%) (USD)
≤ 1.8	28	2.80-14.00	30.80-42.00
2.0-2.7	32	3.20-16.00	35.20-48.00
3.6-4.0	40	4.00-20.00	44.00-60.00
4.5-7.2	48	4.80-24.00	52.80-72..00
8.0-11	64	6.40-32.00	70.40-96.00

Therefore, the design of efficient faecal sludge management systems still stands a challenge because of the obscure data on the quantities and composition of non-faecal solid wastes present in the sludge (Mwale, 2013).

It is however important to note that improvement of Solid waste management in poor urban is the best initiative towards reduction of deposition of solid waste in pit latrines(Strande, 2014). This will largely involve influencing the user habits of users of these pit latrines. However, there are possible engineering interventions that can be put in place to reduce the deposition of solid waste in pit latrines. By and large, these engineering interventions will still remain a limitation in poor urban areas given the unplanned nature of these settlement and the limitations caused by funding.

Largely, the conversion of pit latrines to flush toilets that is pour flush connected to septic would be a move that would rid pits of solid waste. This can however be hampered by the fact that water supply in these poor urban areas is already rationed.

2.5 Faecal sludge management in urban slums

2.5.1 Faecal sludge management chain.

Faecal sludge management (FSM) is the collection transport and treatment of faecal sludge removed from pit latrines, septic tanks or other onsite sanitation systems. The faecal sludge management chain entails containment, collection, transport and treatment to disposal or reuse (GIZ, 2017).

The focus of any faecal sludge management chain is collection and treatment and its efficiency is highly dependent on effective management. There are a number of stakeholders that are involved in the faecal sludge management chain (Strande, 2014). The key stakeholders involved are Ministry of Water and Environment (MoWE), Kampala Capital City Authority (KCCA), National Water and Sewerage Cooperation (NWSC) and the pit emptying associations within Kampala City.

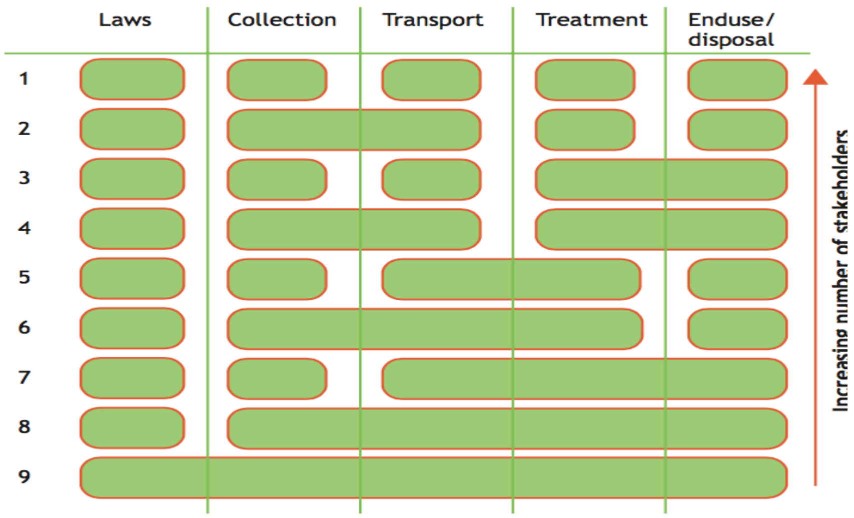


Figure 2-1: schematic showing the chain of faecal sludge management with stakeholder involvement. Source (Strande, 2014)

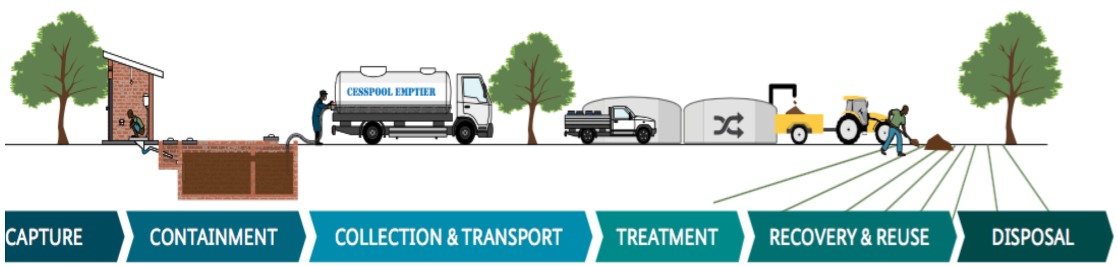


Figure 2-2: faecal sludge management chain source (GIZ, 2017)

2.5.2 Pit Emptying and transportation of faecal sludge

There are considerable practical problems as to how to deal with pit latrines once they fill up, particularly in highly populated areas like slums characterised by limited space for facilities to be moved or for pit emptying equipment to access the plot. Various technologies have been tried in developing countries to address this problem, with varying degrees of success (Thye, Templeton, & Ali, 2011).

The need for pit emptying cannot be overlooked due to the potential disasters posed to the environment and the health of the occupants of such areas. Full and overflowing pits pose a risk of contaminating water sources such as wells and have the potential to enter water supply lines (Thye et al., 2011) .

Faecal sludge can be removed from latrines through the use of manual or mechanised techniques that may rely upon hand tools, vacuum trucks, pumping systems, or mechanical augers. The specific method utilised used is largely dependent on the type of onsite system, accessibility of the site, the type of equipment owned by the service provider, and the level of expertise (Strande, 2014).

Traditional emptying practices usually employ buckets, manual digging, or large vacuum tankers. A number of mechanized pit emptying technologies exist, although none have been proven on a large scale for use in slums (Thye et al., 2011).

In sub-Saharan Africa, manual emptying is widely used in poor urban areas because conventional truck-mounted tankers cannot access the households due to limitations of space, charges are too expensive for users many of whom are low-income earners and the nature of the sludge which is mixed with solid waste (Thye et al., 2011). Also, many pit latrines in slum areas around Kampala are located in areas that vacuum tankers cannot reach since they are far from easy road access. There is, however, significant demand for affordable manual emptying services to address these problems (Gibson, Eales, & Nsubuga-Mugga, 2018).

Manual emptying of pit latrines is done using either scoops or by flushing the contents through a hole in the lining into an adjacent pit. These methods are widely employed in many densely populated areas of SSA in the absence of a viable and affordable tanker service (Still, 2002). However, it is sad to note that these procedures are carried out with Personal Protective Equipment (PPE) like rubber gloves, thick overalls, gum boots and this has jeopardized the health of those involved in such practices (Murungi & van Dijk, 2014).

There has yet to be an ideal solution to pit emptying in slum areas around the world, where access is the main constraint, although potential small-scale technologies have been put in place and tried. Notably, small vacuum tankers have been developed and tested for use in high-density urban areas where access to sites is a problem.

The 200 litre Manual Pit Emptying Technology (MAPET) has been proven in Dar-es-Salaam and the 500-litre Vacutug in Nairobi. However, none of the devices is economical or practical if the sludge has to be disposed of a distance more than one kilometre from the source (Still, 2002).

However, pit latrine emptying tools must consider the latrine sub-structure and superstructure, environmental factors, household practices on use, and characteristics of faecal sludge (FS). This is one of the driving factors in the selection of appropriate emptying technologies (Chiposa, Holm, Munthali, Chidya, & de los Reyes, 2017) .

The responsibility of pit emptying and maintenance is carried out by the pit owners or landlords for the case of rentals. However, most of the landlords do not stay near their tenants or the pit latrines as it is for many slums around Kampala, the pit latrines are therefore usually emptied past the time they are full (Yvonne et al., 2016). This greatly endangers the health of the users of such full pits.

The challenge of pit emptying is further complicated by the fact that the contents in a pit latrine and what happens to them are generally not well understood. In addition to faecal sludges of different densities, researchers have also reported solid particles, wood, stones, and plastics in pits. This has made the use of pumps as an emptying technique in many slums quite difficult. Therefore pit emptying tools need to be able to pump both sludge and solid waste material (Chiposa et al., 2017). However, the emptying of full pits in congested urban areas of Kampala still remains a challenge. Only 24% of emptying takes place in informal settlements (GIZ, 2017).

Collection and transport companies to remove faecal sludge are essential for the proper functioning of onsite systems (Strande, 2014). Some of the means used for transportation of collected sludge from these include trucks, motorized tricycles and carts. Motorised tricycles are the smallest type of low-cost motorised transport use.

Motorised transport equipment offer the potential for larger load capacities and increased speed, leading to reduced travel times and a greater range as compared to manual transport. The operation and maintenance of motorised transport is generally more complex than that of manual transport, however many variations are widely used in low-income countries. Before selecting the type of transport system, it is important to verify that the knowledge and skills to carry out repairs are locally available (Strande, 2014).

2.5.3 Treatment of faecal sludge

Faecal sludge treatment, FST and disposal is a principal component of environmental sanitation. There were no designated locations for the disposal and treatment of FS in peri-urban communities (Effah et.al, 2014). However, few of the dwellers disposed of their faecal sludge a distance from their dwellings through services of the pit emptiers.

Majority (61%) of all FS transports are de-loaded at the Lubigi Treatment Plant and 39% at Bugolobi. This is has however raised serious concerns since the latter is not designed to treat faecal sludge at all and suggests that additional treatment capacity for FS is urgently needed (GIZ, 2017).

2.6 Status and performance of pit latrines in informal settlements of Kampala

It is reported that 95% of households in slums of Kampala use pit latrines with a cement slab or ventilated improved pit latrines (VIPs). However, 84% of the users have to share their toilet with on average 6.7 households or 30.2 individuals . Another study indicated that 51% of the pit latrines were full, 15% overflowing with sludge and a disturbing smell was noted in 39% of the latrines while few flies were found in the majority (80%) of the latrines. 43% of the pit latrines were also reported dirty (Nakagiri et al., 2015).

Majority of the pit latrines (95%) contained their excreta until they were emptied. The rest reportedly discharged directly into open drains and these were all found in flooding areas (Nakagiri et al., 2015). One of the biggest challenges in the usage of pit latrines is their finite capacity which causes them to fill up within a few months or years of usage (Murungi & van Dijk, 2014).

It is also reported that more than 50% of pit-latrines in urban informal settlements of Kampala are un-lined and filled with solid waste and only 20 – 25% of the toilets have ever been emptied by a service provider, the rest have either been abandoned or been emptied directly into the environment, posing health and environmental risks for the city and its people (GIZ, 2017).

CHAPTER THREE: METHODOLOGY

3.1 Introduction

The study sought to design a method for characterisation and quantifying non-faecal solid wastes in the pit latrines. 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, selecting pit latrines to be sampled, sample collection, washing to separate solid waste from feacal sludge, drying solid waste to determine 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 various categories to include; rubble, plastics, glass, textiles (sacks, cloth, sanitary pads and diapers), paper (anal cleansing material), metals, organic waste (including timber and logs) and others (Tembo et al., 2019).

3.2 Study area

The study was conducted in two urban slums of Makerere 3 and Kamwokya 2, Kawempe division. Makerere is bordered by Bwaise to the north, Mulago to the east, Wandegeya and Nakasero to the southeast, Old Kampala to the south, Naakulabye to the southwest. Kasubi and Kawaala lie to the west of Makerere. Kamwookya is bordered by Kyebando to the north, Bukoto to the northeast, Naguru to the east, Kololo to the southeast, Nakasero to the south and Mulago to the west. These study areas were purposively chosen because of their close proximity to the University and Lubigi sewage treatment plant. Also, these slums are unplanned with a lack of basic services, poor road access and poor housing (Kulabako et al., 2005). The targeted pit latrines were those in hard to access areas with poor garbage management systems (areas where there is little or limited garbage collection by KCCA) in low- income peri-urban settlements.

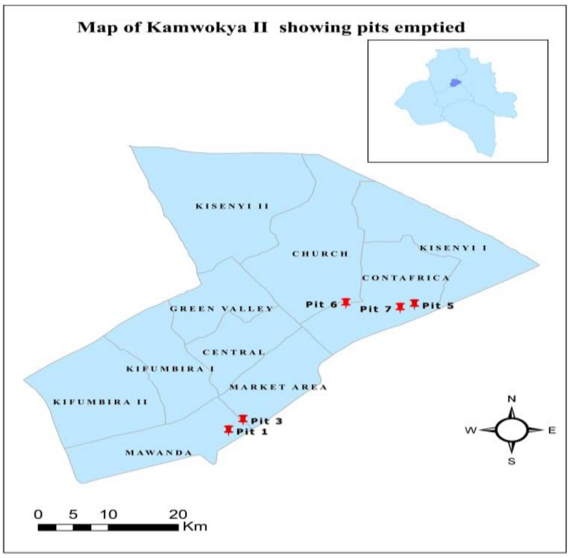


Figure 3-1: Map of Kamwokya II showing emptied pits

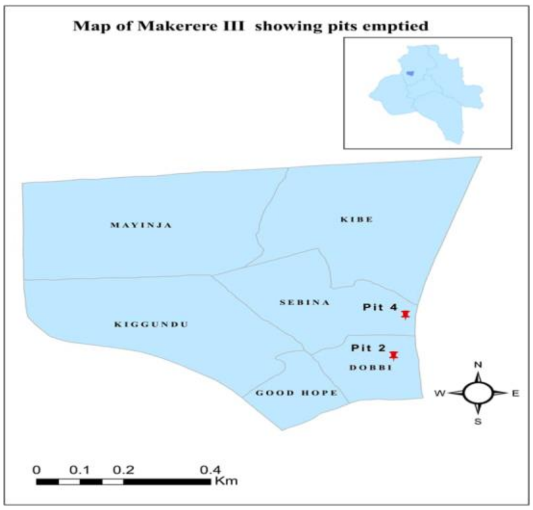


Figure 3-2: Map of Makerere III showing emptied pits

3.3 Data collection

Various methods and techniques were used in obtaining data necessary for carrying out the research. These included;

3.3.1 Questionnaire

A semi-structured questionnaire was used to assess waste collection practices, separation and disposal methods, concerns regarding solid wastes, and willingness to participate in waste separation (Mukama et al., 2016) . The questionnaire also assessed management of faecal sludge in the study areas and the usage of these pit latrines in relation to solid waste.

A total of 150 (n=115 for Kawempe II and n=45for Makerere III each of the study areas) were administered to households within a 200m radius of the emptied pits. The questionnaire was prepared in English, however, most of the interviews were held in Luganda, a popular language spoken among the residents of the slums. The questionnaires are shown in appendix A.

3. 3.2 Observation check list.

This was used to assess the ambient conditions of the surroundings of the pits that were being emptied. The observation checklist is also shown in appendix A.

3.4 Selection of pits

Only households within the study areas utilising pit latrines for disposal of excreta were considered during the study. Only pit latrines that emptied were considered for this study.

Pits meeting the following criteria were chosen for emptying;

- not so deep pits. This was to ensure the pit is fully emptied to give the entire contents
- should be full or nearly full. The depth from slab soffit to sludge surface < 0.5 m
- Dimensions in terms of length, width and depth should be measurable.

3.5 Desludging of the pits.

The emptying of the pits was done using manual methods. The entire contents of the pits were emptied. The emptying was done by Brilliant Sanitation Uganda Limited, a company dealing in emptying of pit latrines in the suburbs of Kampala. The emptying of the pits was done manually employing tools like buckets, jerry cans and hooks.

The sludge was scooped into five litre jerrycan by one of the members and then pulled upwards and emptied into twenty litre jerrycans which were finally emptied into 160 litre drums. The pits were emptied to full depth and when not possible they were emptied to near full depth The sludge was transported to Lubigi treatment plant.

Figure 3-3: a worker manually empties the contents of the pit

Figure 3-4: pit contents being emptied into drums

3.6 Quantification of emptied faecal sludge.

The faecal sludge contained in the barrels was weighed using an automatic scale specified for heavy weights. The total weight of the barrel filled with sludge is recorded as (A) and the weight of the empty barrel recorded as (B).

Figure 3-5: a drum containing sludge being weighed on an automatic scale

The total weight (C) of the sludge collected is given by the formula:

$$C = A - B$$

The depth of the pit latrines was determined by inserting a long stick through the squat hole and then measuring to the marking given by the sludge.. A handheld GPS machine was used to record the coordinate location of every pit latrine emptied during the study. These coordinates were plotted to give a distribution map of the emptied pit latrines.

3.7 Determination of moisture content

The moisture content was determined following standard method 2540G for solids and semi-solid samples (American Public Health Association, 2012). 30 ml of the sample were oven dried at 105^{o}C for 24 hour till a constant mass of the sample was obtained. The sample mass was measured before and after drying. The moisture content was the computed as a percentage of the mass of the wet sample. The detailed procedure for moisture content determination are shown in Appendix B. The moisture content in this study was analysed to aid in the conversion of the excreta and solid waste components to their respective dry masses (Tembo et al., 2019).

3.8 Separation of solid waste and grit from sludge

Separation of the excreta from the solid waste and grit of the faecal was done by means of washing using water on 5mm diameter sieves (Tembo et al., 2017). The sludge was poured out from the top of the sieve and then pressurized water is applied using horse pipe to agitate the contents. The trickling water carried with it with it the liquid component the faecal sludge and was collected in a tapolin placed in a dug out hole. The solid waste was then collected into empty barrels for further thorough washing.

Figure 3-6: drum containing sludge is emptied into the sieve

Figure 3-7: solid waste retained on sieve being washed further

3.9 Quantification of the solid waste.

The solid waste obtained from the washing and sieving process was evenly spread out on tupolins and air-dried for at least two days (Tembo et al., 2019). During the drying period the waste was turned about to ensure that it evenly dries. The dried waste was then be weighed using an automatic electronic weighing scale and the mass will be recorded as (D). Laboratory moisture content (MC) results were used to obtain the total dry mass of the solid contents of the faecal sludge. Dry mass (E) is given by the formula;

$$Dry\,mass = \left(1 - \frac{MC}{100}\right) \times Total\;weight\;of\;sludge$$

The percentage, X, of solid waste in the faecal sludge was calculated from the formula:

$$X = \frac{\mathrm{D}}{\mathrm{E}} \times 100$$

3.10 Composition of the waste

The air-dried waste was hand sorted into the following different categories for the classification of the non-faecal solid waste and placed into plastic bags labelled according to category.

Figure 3-8: waste hand sorted into different categories

In this study, solid waste in the faecal sludge was categorized as; inorganic waste like plastics, glass, textiles for example sacks, rugs, sanitary pads and diapers, paper, and solid metals, and organic waste including vegetation matter like grass, food peelings, plant matter like leaves and roots, wood and others (Tembo et al., 2019). The different categories are briefly explained in Table 3-1.

Table 3-1: Description of the different waste categories

Waste category	**Description**
Organics	This included; mingling sticks, timber pieces and any wooden materials found.
Polyethene	This included; polyethene bags, polythene rapping materials and any other polyethene material found.
Textile	This included; clothes, hair and other textile materials found in the pits.
Plastic	This included; plastic cups, bottles, tins, combs ,straws, bottle caps and any other plastic material found with the exception of polyethene which has its own category.
Glass	This included; soda bottles, glass plates and any other glass material found in the pits.
Sanitary towels	This included; sanitary pads and diapers.
Rubber	This included; condoms, rubber tyres and any other rubber material found in the pits.
Metals	This included metallic forks, cups ,tins and any other metallic material identified.
Paper	This included all paper material found in the pit.
Rubble	This included; broken bricks ,stones and soil found in the pits.
Other	This included; any very small and not easily unidentifiable materials found in the pits.

These were weighed and then expressed as percentages of the total weight of air-dried solid waste. The percentage by composition is calculated using the formula;

$$percentage\ composition\ (\%) = \frac{w_c}{w_t}$$

Where;
w_c is the weight of the category of solid waste and w_t is the total weight of the solid waste

3.11 Composition of solid waste in the study area

The composition study was carried out on waste dumps within a 50m radius of the pits that were being emptied. The composition of solid waste generated in the study area was carried out by segregating it into different component for example kitchen waste, paper, earth and fine material, slaughter house waste, leaves, metals, textile to mention but a few. These components were then categorised into organic waste and inorganic waste (Namdeo et al., 2010) . Five kilogram samples were collected from random kips or waste dumps and the waste sorted into different waste categories. A total of four samples, two from each slum were taken for composition study.

Table 3-2: Municipal Solid waste components for solid waste characterisation source (Ozcan et al., 2016)

Waste component	Description
Organics	Food wastes
Paper	Newspapers, magazines
Cardboard	Cardboard boxes
Plastics	Plastics except for PET
Glass	Jars, colourful and colourless glasses
Metals	Iron metals, cans and aluminium materials
Garden waste	Wood and other garden wastes
Textiles	Clothing, carpets, bags, shoes
Sanitary materials	Diapers, Pads
Rubber	Slippers, condoms,

3.12 Analysis of results

The data was analysed using excel software to generate graphs and statistical descriptions. Statistical analysis however bases on the assumption that a set of data arises as a sample from a distribution from some probability distributions. Mean results are computed based on the solid waste samples taken from each of the pit latrines. Sample standard deviation was computed to measure the degree of spread of the data. The overall mean for both solid waste was computed by summing up all the individual results. These were used to generate statistical graphs and pie charts.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This section presents results of the study. The results presented include moisture content , current status of solid waste and faecal sludge management, municipal solid waste composition, composition of solid waste in the pit latrines in the study area. Analysis was done using the methods presented under the Methods chapter.

4.2 Current state of solid waste management in the study area

4.2.1 Temporary Storage for municipal solid waste

It was observed that 63.47% of the households temporarily stored their wastes in sacks, 20.2% in polyethene before disposal and 16.33% of the households did not have waste storage means and said they directly accessed nearby dumping sites.

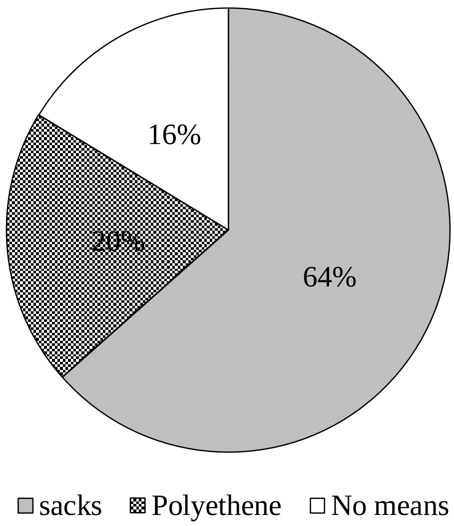


Figure 4-1: temporary storage of solid waste by households

The sacks being popularly used among these households can be attributed to their durability, capacity and re-usability as compared to polythene. Sacks can also store waste for a considerable period of time and are easily as compared to polyethene.

A similar study by Ssemugabo et al., (2020) that was carried out in Kasubi parish in Rubaga division revealed that the majority of the households 85.8% owned solid waste storage receptacles, most of which were sacks 61.7% .

4.2.2 Municipal solid waste separation

The study showed that majority of the households (66.33%) did not carry out any form of waste segregation at household level. Only 33.67% of the households that participated in the study reported carrying out some form of waste segregation at the household level as shown figure 4-2 below. The particular waste stream of interest segregated was organic waste especially food peelings like matooke and sweet potato peelings which were mainly collected as animal feed by those that owned animals or their neighbours. There was an awareness of value of certain specific waste streams particularly organic wastes which were separated at the source of generation.

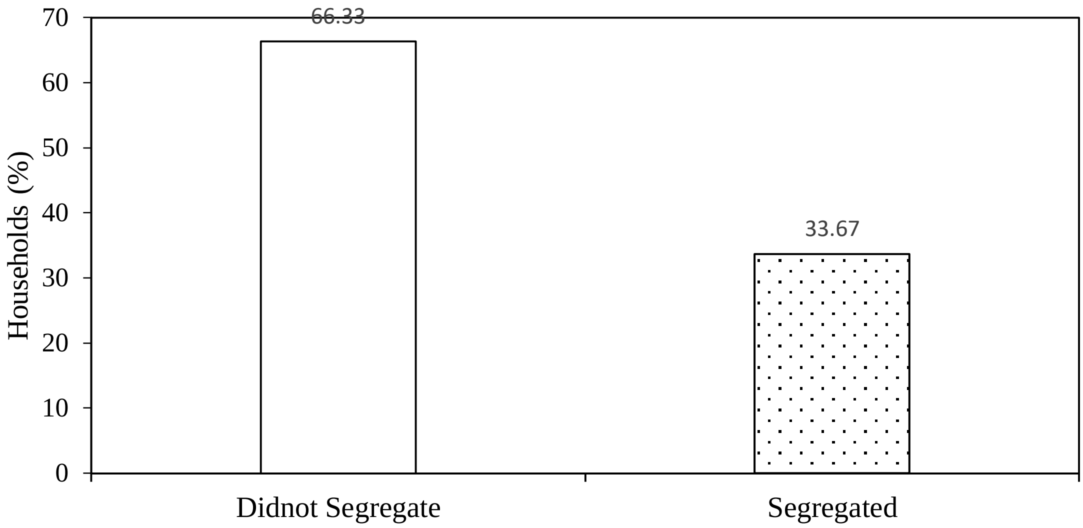


Figure 4-2: household segregation of solid waste

The minimal willingness of these respondents to segregate solid waste at their respective households can be attributed to the lack of incentive to motivate segregation of solid waste household level. Household waste segregation could also be hampered by the fact these people have limited resources in terms of storage containers to carry out segregation of their waste. Also, time could be a limiting factor (Yoada, 2019).

In relation to other studies, Ssemugabo et al., (2020) found out that the main type of waste collected in Kasubi Parish, Rubaga division was biodegradable materials 56.7% and the majority of the households 78.7% did not segregate their waste.

4.2.3 Collection and disposal

Regarding waste collection and disposal, the study revealed that the majority (73.64%) of the respondents did not have their waste collected from them and 26.36% of the households had their solid wastes picked up by collection trucks. Of the 73.64% that didn't have their waste collected, 48.69% openly dumped their solid waste in nearby waste dumps and in drainages while 24.95% burnt their solid waste but on small scale as shown in figure 4-3.

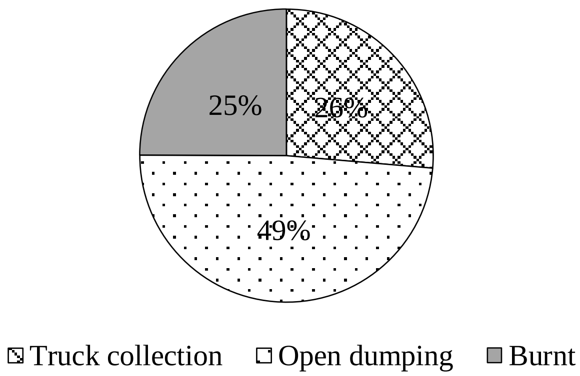


Figure 4-3: collection and disposal of municipal solid waste in the study area

The poor collection of solid waste which has forced residents into unhygienic practices like open dumping can be attributed to the inadequate solid waste management in these areas.The management of solid waste in these areas is based on the local government's centralized collection, transportation and disposal strategy. However, this approach has proved to be inefficient due to the heavy financial requirements involved (Nyakaana, 2012). As such collection of municipal solid waste remains wanting in many slums around Kampala. According to Ssemugabo et al., (2020), only a third of the total waste generated in slum communities in Kampala is collected and disposed of to the landfill every month. Also, these areas are generally unplanned and inaccessible which makes any attempt to collect waste from households a challenging task (Ssemugabo et al., 2020).

It can also be noted that Kampala Capital City Authority (KCCA) supports the collection of garbage generated at household level at a subsidized fee. However, slum dwellers forfeit this service because of unaffordability and ignorance of importance solid waste management services (Ssemugabo et al., 2020). This unwillingness of the slum dwellers to actively participate in management of solid waste also frustrates the attempts to collect municipal solid waste at household level.

Generally, the collection of municipal solid waste (MSW) has been identified as a major problem particularly in urban informal settlements since in many areas municipal authorities are either unable or unwilling to provide waste collection services to all residents in their jurisdiction (Al-Khatib et al., 2010).

Also, given the fact these areas are characterized by dense population, disposal problems become more difficult. Therefore, there is greater production of waste and decreased proportion of land availability for its disposal (Namdeo et al., 2009).

A small number (10.64%) of the respondents admitted to having used their pit latrines as an alternative for disposal of solid waste citing particular waste categories such as broken glass, sanitary materials like pads, pampers, needles, razor blades .

4.3 Status of faecal sludge management

It was observed that majority of the respondents, 74.67% (112/150) had pits that were near full and 25.33% (38/150) had pits that were already full and necessitated emptying as shown in figure 4-6. The above statistic can be attributed to the quick filling up of pit latrines in slum areas since they are shallow (not more than 2.64m in depth) and have many users (Katukiza et al., 2010). Most of them are also used as an alternative for solid waste disposal as well (Zziwa et al., 2016). Also according to Nakagiri et al., (2015), the performance of pit latrines Kampala’s poor urban areas was found to be inadequate with seven in every ten pit latrines either full or overflowing and majority of them filled in three months or less.

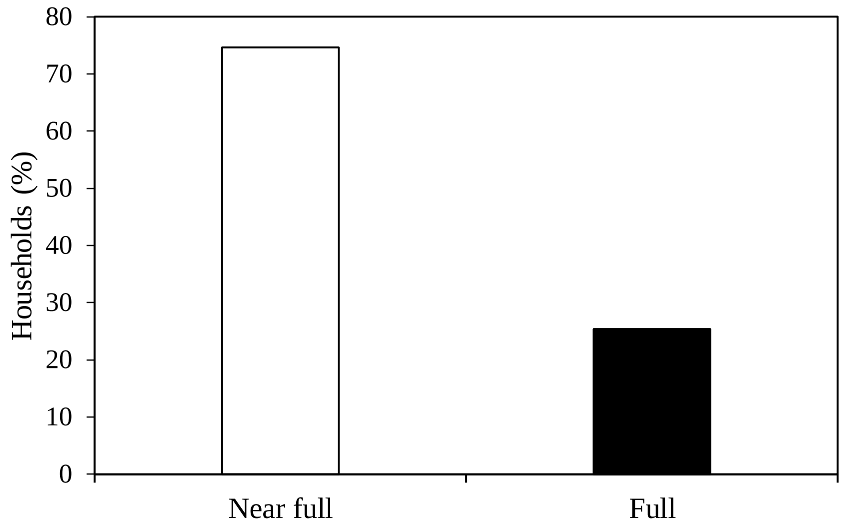


Figure 4-4: percentage of full and nearly full pits in the study area

Of the 25.33% of the households whose pits were already full, 68.78% had never had their pits emptied before while 31.22% had ever emptied their pits. Also , 60.73% of these household reported that it was the responsibility of their landlords to empty the full pits, 13.65% thought the emptying of the full pit was a collective responsibility of the users of the pit latrine and 25.62% had no idea of what was to be done next as shown in figure 4-7 below.

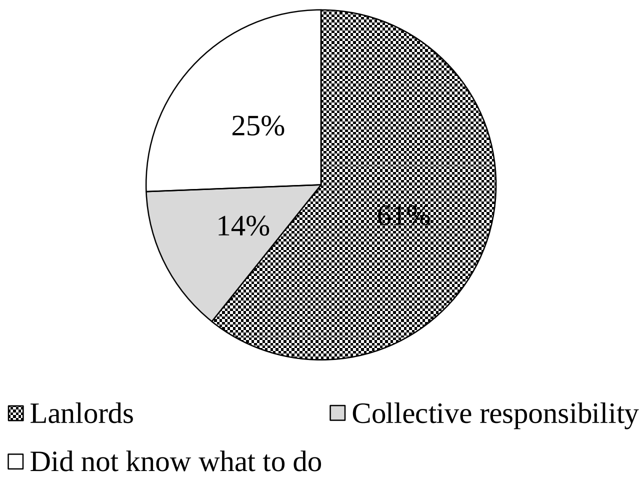


Figure 4-5: possible parties responsible for emptying

The study showed that a large number , 78.6% of the 150 households interviewed used paper as anal cleansing material while 21.4% (32/150) used water as shown in figure 4-8. The difference can be explained by difference in beliefs and religious practices.

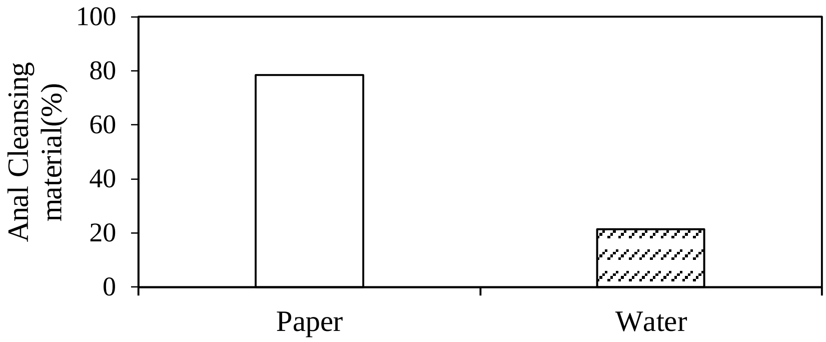


Figure 4-6: households that used either water or paper as anal cleansing material

4.4 Composition of municipal solid waste in the study area

A composition study that was carried out around six dumps within a 50m radius of the pits being emptied revealed that a largest component (65.92%) of the waste was organic waste and 34.08% of the waste was inorganic wastes. The organic waste is much higher in composition than the inorganic waste due to the high consumption of agricultural produce which contributes largely food debris inform of peelings like matooke, cassava and Irish potato peelings.

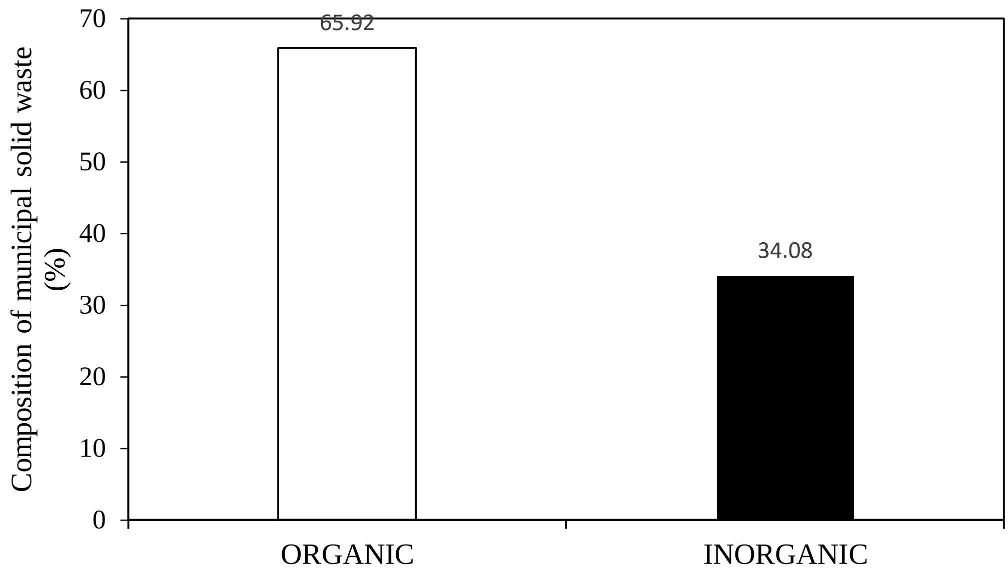
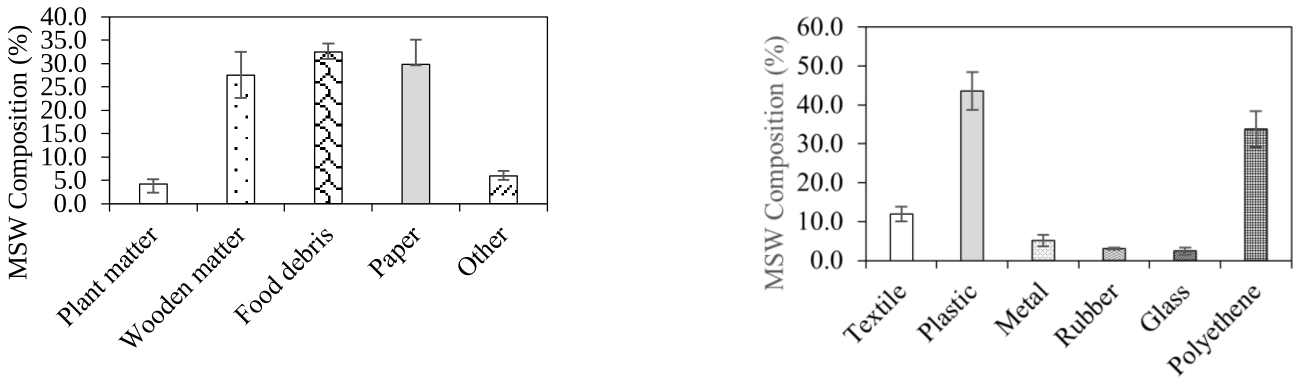


Figure 4-7: composition of organic and organic wastes in waste dumps around the study area

In relation to other studies , according to Namdeo et al., (2010) 61% of the waste generated was organic waste, and the rest is inorganic waste. In addition, a study by Philippe & Culot, (2009) also observed that the organic matter represented 65.5% of waste by weight of the total waste that was generated. Also, according to Nyakaana,(2012) the solid waste generated in Kampala City is largely composed of vegetable matter (70%) from discarded foods.



(a)

Figure 4-8: different components of organic waste (a) and inorganic waste (b)

It can be seen from figure 4-5 that the major component of organic waste was food debris 32%, followed by paper 30%, wooden matter 28%, others 6% and plant matter 4%. The main component of the inorganic waste was plastic 44%, polyethene 34%, textile 12%, metal 5%, rubber 3% and glass 2%.4.4 Solid waste composition in pit latrines

The study indicated that the composition of solid waste in the emptied pits of Kawempe II greatly varied with the different categories as shown in figure 4-9. Rubble constituted 29.5±26.9%, followed by paper 17.64±17.8%, polyethene 8.22±8.1%, textiles 7.08±4.80%, sanitary towels 6.88±4.7%,organics 4.6±3.9%, plastics 1.74±0.4%, and glass 1.5±1.6%. There were trace amounts of metal (0.42±0.4%) and rubber (0.24±0.2%) that were observed.

It was also found that the composition of solid waste in the emptied pits of Makerere III greatly varied with the different categories. Textile constituted 21.35±2.35%, followed by sanitary towels 15.15±9.35%, rubble 13.4±2.8%, paper 11.65±5.55%, polyethene 11.25±0.75%, organics 6.25±1.55%, plastics 1.35±0.05%, glass 0.2±0.2%. Similarly there were trace amounts of metals and rubber from the pits.

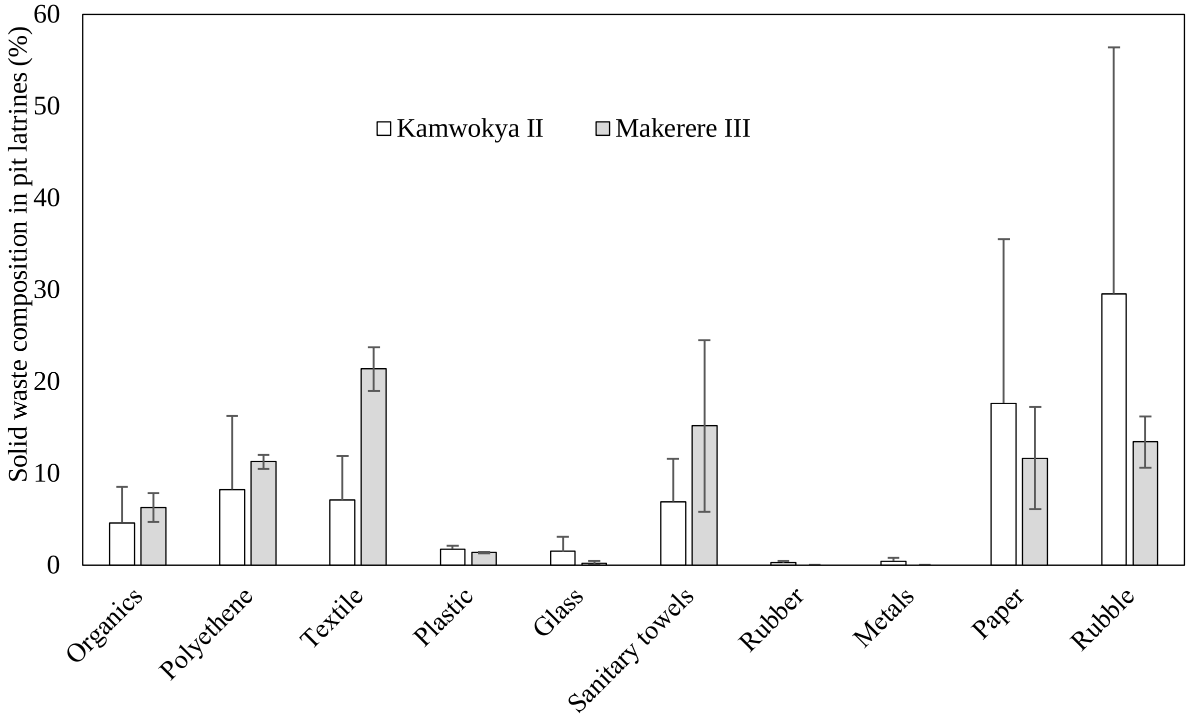


Figure 4-9: variation of solid waste in the emptied pits of Kawempe II and Makerere III

Rubble constituted the highest percentage because more than 75% of the emptied pits (pit 1, Pit 3, Pit 5 and Pit 7) were unlined pits which were therefore susceptible to collapse during their usage and also during emptying process yielding rubble waste.

Paper was also a dominant waste category because it was largely used as anal cleansing material. With reference to the questionnaires and interviews that were held, it was observed that the majority of the households 78.6% used paper as anal cleansing material. In addition, the composition study of municipal solid waste in Chapter 4.3 above also showed that paper was was one of the dominant components of organic wastes in waste dumps of these communities giving a composition of 30% (figure 4-5(a) above).

Trace amounts of metals and rubber were observed likely because there is a tendency to openly dump these wastes for example the sight of littered condoms and other small rubber elements was common in most of these areas. The robust scrap dealing businesses that have taken up metal collection from the communities could be a possible explanation as to why trace amounts of metallic waste ended up in the pit latrine.

There was considerable amount of glass obtained from these pits as well. The study area in Kamwokya II was particularly surrounded by bars. This could possibly be a contributing factor to the amount of glass that was contained in the pit latrines. However in reference to the composition study of the municipal solid waste in Chapter 4.3 above, it was observed that rubber and glass were the least components of inorganic waste contained in the waste dumps yielding compositions of 3% and 2% respectively. This could possibly explain why they occurred in very trace amounts in the pit latrines as well.

Textile which largely comprised of tattered mattress and old clothing was dominant waste category in the emptied pits of Makerere III. Particular wastes in both study areas can also be linked to specific age groups and sex for example pampers for children and sanitary products for the females.

The state of infrastructure of the pit latrines as well influenced particularly the amount of inert solid wastes (stone and silt) that were contained in the sludge. A study by (GIZ, 2017) reported that more than 50% of pit-latrines in urban informal settlements of Kampala are un-lined. Furthermore, more rubble appeared to have fallen into the pit during the desludging process. This arguably justifies the presence of rubble as a dominant waste category in both Kamwokya II and Makerere III.

However, it was observed that Makerere III posted higher percentage composition of organics, polyethene, textiles, sanitary towels compared to Kamwokya II. This can be attributed to the smaller number sampled pits in Makerere III (n=2) compared to Kamwokya II (n=5).

In general the study on the characterisation of solid waste in the slums showed a composition of 11.2±8.3% textiles, 1.6±0.4% plastics, , 5.1±3.8% organic waste, 15.1±16.8% paper, 0.3±0.4% metal and 1.1±1.6% glass, 24.9±25.8% rubble as shown in figure 4-10

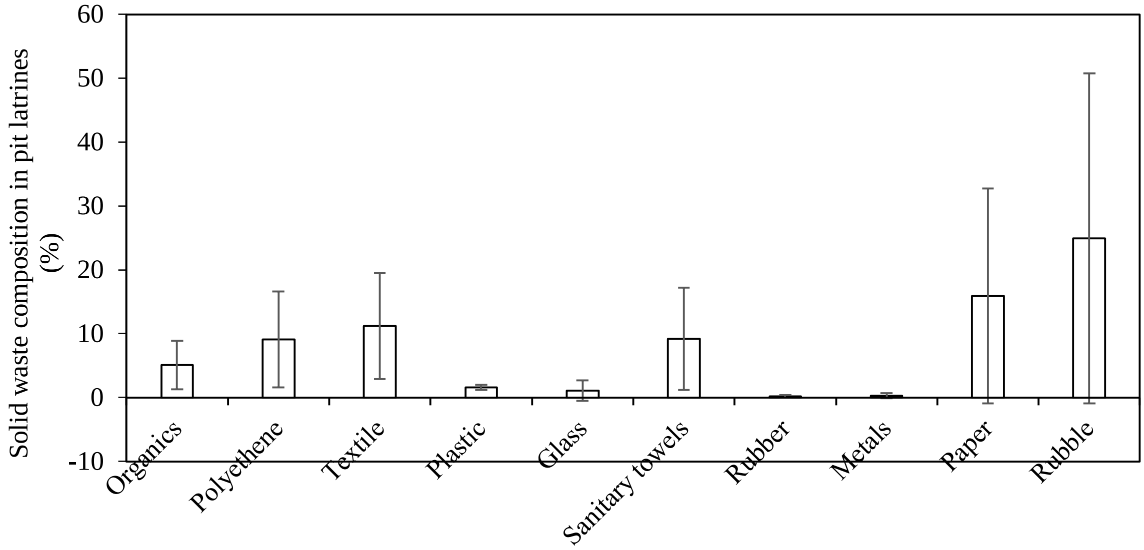


Figure 4-10: variation in total composition of solid waste in emptied pit latrines (n=7)

However, a similar study by Tembo et al., (2019) on the characterisation of the solid waste in the faecal sludge 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 variation can be due to the fact the study by Tembo et al., (2019) considered n=24, 60Litre drums of faecal sludge from the pits whereas this particular study considered the entire contents of the pit with n=93 and 160Litre drums from the seven pits.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study shows that the management of municipal solid waste in the study area is still lacking. In general these areas were characterized by inadequate management of solid waste in terms of collection and disposal, characterized by poor disposal of solid waste mainly open dumping. Also, majority

The study also reveals that the management of faecal sludge is still wanting within urban informal settlements. Many of the slum dwellers are finding it difficult to empty their full pits due to the costs involved.

The study revealed that the composition of municipal solid waste largely consisted of organic waste (65.92%) and inorganic wastes (34.08%). The largest components of organic waste was food debris (32%) and paper (30%).

The characterisation and composition of solid waste in the pit latrines was achieved . The results show that there was significant content of solid waste in the pit latrines with paper contributing the highest percentage (15.1±16.8%) of the organic waste. The results also show that rubble posted the highest percentage of the inorganic waste (24.9±25.8%).

However, it was observed that there was a slight correspondence between the composition of municipal solid waste within these communities and that of the solid waste contained in the pit latrines.

5.2 Recommendations

Further studies should be carried out on the composition and characterisation of solid waste in pit latrines in slums basing on the volume as the studies done to date have largely considered the percentage weights of the solid waste in pits. This would paint a clearer picture of the problem that solid waste pose in pit latrines.

City council should make an amendment of the policy regarding emptying of pit latrines and septic tanks to make sure that the responsibility for emptying pit latrines is onto both the landlords and tenants. This can be achieved through coming up with a percentage of the rent set aside to cater for the emptying of the pit. This fund serves as an assurance that the pit can easily be emptied at any time of their desire.

There is need for greater intervention amongst the authorities and stakeholders that are concerned with the state of affairs of these areas as regards sanitation in services like solid waste collection and faecal sludge management.

5.3 Limitations

The study largely relied on visual characterisation of solid waste. As such, the decay aspect of some organic waste in the pit latrines was not examined.

Initially the study was aimed at emptying 20 pit latrines however due to time and financial constraints we on emptied a total of seven pits. Secondly, the sieve we used wouldn't collect the smallest fine particle like grit, these escaped with the faecal sludge as it was being washed down the collection tank.

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APPENDICES

APPENDIX A : QUESTIONNAIRE AND OBSERVATION CHECK LIST

QUESTIONNAIRE

This is a questionnaire for a fourth year Civil Engineering Project titled 'Quantification and composition of solid wastes in pit latrines of urban informal settlements for appropriate management'. Please kindly provide objective, truthful and complete responses in this questionnaire. Please note that your consent is highly sought before this questionnaire can be administered. Your views on this topic are highly treasured and the responses you provide are completely anonymous and confidential. The research outcome and report will not include reference to any individuals.

Instructions

Please respond by circling an objective or filling the spaces below the questions.

1. Have you ever emptied the pit latrine?
   A. Yes
   B. No
2. If yes, how often do you empty the pit latrine?

………………………………………………………………………………

3. Who is responsible in case the pit is full? What do you do

……………………………………………………………

4. Do you dump solid waste in the pit latrine?
   A. Yes
   B. No
5. If yes, what are the types of solid waste do you dump in the pit latrine?
   A. Hygienic product
   B. Food waste
   C. Other
6. How many people are in your household?

………………………………………………………………………………

7. Do your share the pit latrine with other households?
   A. Yes
   B. No
8. If yes, how many households share the pit latrine?

……………………………………………………………………………

9. What is used for anal cleansing?
   A. Paper
   B. Water
   C. Other (Specify)

…………………………………………………………………………

10. How is the solid waste generated by this household stored temporarily?

A. Polyethene
B. Sacks
C. other (specify)

10. Is there any separation of waste as generated by the household?
A. Yes
B. No

11. If yes, what waste stream (waste category) are you interested in the most?
…………………………………………………………………………………

12. Is your solid waste generated collected from your household?
A. Yes
B. No

13. If so, what is the frequency of collection?
A. Weekly
B. Fortnightly
C. Monthly
D. None

14. What is the most preferred method of solid waste disposal?
A. Open dumping
B. Burning
C. Composting
D. Collected by trucks

15. What general views can give regarding the management of solid waste in this area? Are there any suggestions toward improvement of solid waste management?
……………………………………………………………………………………………………
……………………………………………………………………………………………………

OBSERVATION CHECKLIST

General Information

Location; …………………………. Date; …………………

Weather; …………………

General Observation

Instruction; Provide a small cross or tick in the box where applicable (X or ✓)

1. Nature of the pit

Lined pit ☐
Unlined pit ☐

2. Condition of access to the property

Accessible to hand-carried emptying equipment only ☐
Reasonable access for small (manual or mechanized) emptying equipment ☐
Good access for medium/large size (mechanized) emptying equipment ☐

3. Type of emptying service provided

Mechanised / Vacuum technologies ☐
Semi-Mechanised / Non-vacuum technology (Specify) ……………………… ☐

4. Does the emptying procedure leave fresh faecal sludge exposed in the compound?

Getting access results in significant amounts of faecal contamination of the surrounding area ☐
Getting access results in small amounts of faecal contamination of the surrounding area ☐
Others (specify) …………………………………………………………………

5. Was the pit overflowing before emptying?

Yes ☐
No ☐

6. Was the pit latrine fully emptied by the technology?

Yes ☐
No ☐

7. What was the quantity of water added before emptying was carried out?

…………………………………………………………………………………………………

8. Does the sludge emptied contain solid waste?

Yes ☐
No ☐

9. If yes, what are some of the materials (solid waste) contained in the sludge

APPENDIX B: EXPERIMENT PROCEDURE

Equipment :

Crucibles, desiccator, weighing scale and muffle furnace.

Procedure :

i) Crucibles were first ignited in an oven at 103-105 °C for 30minutes before use and were then put in a desiccator for 15minutes to cool down.
ii) The mass of the crucible was measured and recorded.
iii) Approximately 7.5ml of the solid FS sample was added to the crucible. The mass of the crucible plus the sample was recorded.
iv) The crucible and its constituents were placed in an oven at 105 °C for 18-24 hours.
v) The Dry samples were then removed from the oven and placed in a desiccator to cool.
vi) The weight of the dry sample and the crucible was then taken and recorded.
vii) The Dry sample was then placed in a muffle furnace and ignited at 550 °C for 2 hours.
viii) The weight of the residue and the crucible after ignition was then measured and recorded.

The moisture content (MC) was then attained basing on the expression below:

$$\textbf{MC}\ (\%) = \frac{(C-B)-(A-B)}{(C-B)}\ x\ 100\%$$

where:

A = Weight of dried residue + crucible, g.
B = Weight of crucible, g.
C = Weight of wet sample +crucible, g.

APPENDIX C: CALCULATIONS

MOISTURE CONTENT CALCULATIONS

Table 0-1:moisture content calculations

Characteristics of fresh sludge from Pit 1				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	40.6984	68.378	44.4293	86.52
2	40.0964	67.9001	43.8433	86.52
3	39.8128	68.0203	43.6185	86.51
Average				86.52
Characteristics of fresh sludge from Pit 2				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	55.2	87.22	58.99	88.16
2	64.35	97.16	67.25	91.16
Average				89.66
Characteristics of fresh sludge from Pit 3				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	59.44	88.22	65.29	79.67
2	51.36	87.19	55.25	89.14
Average				84.41
Characteristics of fresh sludge from Pit 4				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	59.6	78.45	62.37	85.31
2	51.1	73.55	54.52	84.77
Average				85.04
Characteristics of fresh sludge from Pit 5				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	64.27	108.11	69.26	88.62
2	55.05	101	60.06	89.1
Average				88.86
Characteristics of fresh sludge from Pit 6				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	39.28	67.97	40.9923	94.05
2	38.2	63.78	39.9901	93.02
3	45.04	71.52	46.9487	92.8
Average				93.29

Characteristics of fresh sludge from Pit 7				
Sample	**B (g)**	**C (g)**	**A (g)**	**MC (%DS)**
1	42.2498	70.9674	46.3819	85.61
2	42.0754	72.2943	46.5516	85.19
3	40.0849	71.8679	44.6973	85.49
Average				85.43

SOLID WASTE CALCULATIONS

Table 0-2: composition by mass of solid waste in emptied pits

Category	**Mass (kg)**								
	Pit 1	**Pit 2**	**Pit 3**	**Pit 4**	**Pit 5**	**Pit 6**	**Pit 7**	**Average**	**SD**
Organics	1.68	0.76	2.18	0.82	0.24	3.94	0.24	1.41	1.33
Polyethene	0.51	1.95	1.9	1.1	0.1	5.41	6.21	2.45	2.4
Textile	1.42	3.84	2.07	2	0.16	5.18	3.79	2.64	1.71
Plastic	0.67	0.21	0.28	0.15	0.28	1.49	0.43	0.5	0.47
Glass	0.21	0.07	0.04	0	0.35	3.36	0	0.58	1.23
Sanitary Towels	2.46	3.96	2.16	0.61	0.38	0.84	3.5	1.99	1.43
Rubber	0.04	0	0.05	0	0	0.43	0.09	0.09	0.15
Metals	0.1	0	0.05	0	0	1	0.15	0.19	0.36
Paper	6.38	2.78	8.48	0.64	3.1	0	0	3.05	3.29
Rubble	13.12	2.62	0.89	1.11	4.5	67.87	0	12.87	24.66
Other	19.28	0	0	4.08	2.19	1.54	13	5.73	7.47
Total	45.87	16.19	18.1	10.51	11.3	91.06	27.41		

Table 0-3 :percentage composition of solid waste in the emptied pits

Category	**Percentage Composition (%)**								
	Pit 1	**Pit 2**	**Pit 3**	**Pit 4**	**Pit 5**	**Pit 6**	**Pit 7**	**Average**	**SD**
Organics	3.7	4.7	12	7.8	2.1	4.3	0.9	5.1	3.8
Polyethene	1.1	12	10.5	10.5	0.9	5.9	22.7	9.1	7.5
Textile	3.1	23.7	11.4	19	1.4	5.7	13.8	11.2	8.3
Plastic	1.5	1.3	1.5	1.4	2.5	1.6	1.6	1.6	0.4
Glass	0.5	0.4	0.2	0	3.1	3.7	0	1.1	1.6
Sanitary towels	5.4	24.5	11.9	5.8	3.4	0.9	12.8	9.2	8
Rubber	0.1	0	0.3	0	0	0.5	0.3	0.2	0.2
Metals	0.2	0	0.3	0	0	1.1	0.5	0.3	0.4
Paper	13.9	17.2	46.9	6.1	27.4	0	0	15.9	16.8
Rubble	28.6	16.2	4.9	10.6	39.8	74.5	0	24.9	25.8
Others	42	0	0	38.8	19.4	1.7	47.4	21.3	21.3

SOLID WASTE COMPOSITION IN DUMPS

Table 0-4:composition of solid waste in dumps

Sr	Component of solid waste	Composition g/5kG	Composition (%)
Organic			
	Leaves	200	5.8
	Wooden matter	920	26.6
	Food debris	1200	34.7
	Paper	960	27.8
	Other	175	5.1
	Total	3455	100.0
Inorganic			
	Textiles	230	14.9
	Plastic	635	41.1
	Metal	120	7.8
	Rubber	45	2.9
	Glass	65	4.2
	Polyethene	450	29.1
	Total	1545	100.0
ORGANIC +INORGANIC		5000	
DUMP 2			
Sr	Component of solid waste	Composition g/5kG	Composition (%)
Organic			
	Leaves	150	4.4
	Wooden matter	890	25.9
	Food debris	1054	30.6
	Paper	1115	32.4
	Other	230	6.7
	Total	3439	100.0
Inorganic			
	Textiles	160	10.2
	Plastic	798	51.1
	Metal	75	4.8
	Rubber	45	2.9
	Glass	33	2.1
	Polyethene	450	28.8
	Total	1561	100.0

ORGANIC +INORGANIC		5000	
DUMP 3			
Sr	Component of solid waste	Composition g/5kG	Composition (%)
Organic			
	Leaves	97	3.4
	Wooden matter	1020	35.7
	Food debris	970	33.9
	Paper	638	22.3
	Other	135	4.7
	Total	2860	100.0
Inorganic			
	Textiles	280	13.1
	Plastic	780	36.4
	Metal	95	4.4
	Rubber	75	3.5
	Glass	35	1.6
	Polyethene	875	40.9
	Total	2140	100.0
ORGANIC +INORGANIC		5000	
DUMP 4			
Sr	Component of solid waste	Composition g/5kG	Composition (%)
Organic			
	Leaves	120	3.5
	Wooden matter	750	21.9
	Food debris	1050	30.6
	Paper	1260	36.7
	Other	250	7.3
	Total	3430	100.0
Inorganic			
	Textiles	150	9.6
	Plastic	720	45.9
	Metal	55	3.5
	Rubber	45	2.9
	Glass	30	1.9
	Polyethene	570	36.3
	Total	1570	100.0
ORGANIC +INORGANIC		5000	

APPENDIX D: PICTORIAL