ASSESSING THE EFFECTIVENESS OF ON-SITE FECAL SLUDGE EMPTYING TECHNOLOGIES IN DELIVERING SAFELY MANAGED SANITATION SERVICES IN KAMPALA.

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A DESRTATION SUBMITTED TO FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY

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ABSTRACT

The research study investigated the effectiveness of on-site fecal sludge emptying technologies in delivering safely managed sanitation services in Kampala. The study focused on cesspool and gulper technology operations in Kampala with a sample space of 68 operators both companies and sole proprietors.

The study identified the technological, human and environmental health gaps in the technologies that hinder their effectiveness in delivering safely managed sanitation services using survey questionnaires and laboratory analysis. The study identified improvements that can be adopted by the technologies to operate effectively across the sanitation service chain these included modification of gulper technology by introducing a simple fuel-powered motor with a potable pump end that can suck the fecal sludge with minimal energy requirement from the operator.

The research study discovered that both cesspool and gulper technologies do not fully empty the clients containments considering septic tanks, Ventilated improved pit latrines and traditional pit latrines. The gulper technology takes more than one hour to empty containments which is not the case for cesspool technology. The research identified gulper technology to be associated with more environmental and public health risks compared to the cesspool technology.

The study recommended Installation of GPS equipment on all cesspool vacuum trucks and gulper technology operators tricycles to track movement and ensure that the fecal sludge is only disposed at the fecal sludge treatment plant to curb environmental and public health risks identified by the research study.

DECLARATION

I, **Namale Caroline** hereby declare that this is my original work, is not plagiarized, and has not been submitted to any other institution for any award.

Student's name: Namale Caroline

Signature: Date: 5th April 2025

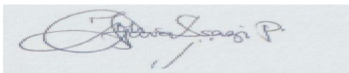
DEDICATION

This research is dedicated to Viva Con Agua Uganda, my family, and my supervisor, Mr Job Ssazi Pius for the support they rendered to me during this study.

APPROVAL

This piece of work has been approved by

Supervisor: MR. Gava Job Ssazi Pius

Signature: 

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List of Acronyms

BOD_5 – Biological Oxygen Demand

CAWST- Centre for Affordable Water and Sanitation

COD – Chemical Oxygen Demand

DO - Dissolved Oxygen

FS – Fecal Sludge

FSM – Fecal sludge management

GoU – Government of Uganda

KCCA-Kampala Capital City Authority

NEMA – National Environmental Management Authority

NWSC- National Water and Sewerage Corporation

PPEs – Personal Protective Equipment

PVC - Poly Vinyl Chloride

SOPs – Standard Operating Procedures

TS- Total Solids

TVS- Total Volatile Solids

VIP – Ventilated improved pit latrine

WHO – World Health Organization

CHAPTER ONE

INTRODUCTION

1.0 Background Information

Sanitation is fundamental to human and environmental health. With rising population growth rates worldwide, the demand for improved sanitation services continues to increase since access to sanitation is considered a human right(Ross & Smith, 2007).

Sanitation services are categorized into off-site and on-site sanitation, 41% of the world's population with improved sanitation services is utilizing the on-site sanitation service where human excreta is stored in a septic tank or a wet or dry pit latrine. The use of off-site and on-site sanitation varies between regions with the on-site sanitation category being common in developing countries(UNICEF & WHO, 2020).

In Uganda, the sewer pipe network is 762km with 24,514 connections to the off-site sanitation service leaving the biggest percentage of the population using the on-site sanitation services(*GoU Ministry of Water and Environment NRECCLWM APPR 2023*, 2023).

Nearly 99% of the population in Greater Kampala is currently connected to on-site sanitation services (McConville et al., 2022) such as pit latrines and septic tanks which all require emptying at some point, where pit latrines are predominant with 66% of users (Nkurunziza & Kwebiha, 2017).

The most commonly used emptying technologies in Kampala are cesspool emptier and gulpers, these provide emptying services mainly to institutions and households. As the population increases, the demand for emptying services has also increased tremendously.

"Even if plans to expand the sewer networks are achieved, at least 70% of the population will remain connected to on-site sanitation services in 2040"(McConville et al., 2022).

Most of the households have unlined pit latrines due to financial constraints and sanitation containments knowledge gap, hence the usage of gulper technology to provide the emptying services, these also work best in hard-to-reach places especially in informal settlements.

The technological and environmental sustainability aspects come into question during the process of extraction of the fecal sludge from the point where its stored either in a pit latrine or a septic tank.

Leakages during the transportation of the fecal sludge, and perforated drums which store it, are some of the exposure routes to the human resource handling the fecal sludge at this stage of the sanitation service chain. This raises health concerns that need to be assessed and recommendations given to inform the occupational health and safety guidelines that guide the implementation of the emptying activity.

1.1 Problem Statement

Nearly 99% of the population in greater Kampala is connected to the on-site sanitation service category(McConville et al., 2022). With the increasing population and the rural-urban migration phenomenon due to the development of urban centers, the demand for fecal sludge emptying services from the on-site sanitation service category has also increased. This has raised environmental concerns such as leakages and final disposal which lead to exposure to pathogenic organisms which are a threat to the environment and human health and technological sustainability concerns including access, desludging depth, and capacity which limit the efficiency and functionality of these technologies.

1.2 Main Objective

To assess the technological and environmental effectiveness of on-site fecal sludge emptying technologies in Kampala.

1.3 Objectives

The study was hinged on three specific objectives that define effectiveness of a safely managed sanitation service across the sanitation service chain.

1. To examine the technological and operational gaps of fecal sludge emptying technologies
2. To identify the environmental risks and health concerns associated with fecal sludge emptying technologies
3. To identify improvements and best practices that can be adapted across the sanitation service chain to ensure safe fecal sludge management.

1.6 Research Questions

1. What are the existing technological gaps in the identified emptying technologies?
2. Which environmental and health concerns do the emptying technologies pose?
3. What improvements can be adapted to ensure safe fecal sludge management during emptying?

1.5 Scope of Study

Conceptual Scope

The research is limited to examining mechanized emptying, particularly cesspool emptying, and gulper emptying technologies. The focus of the manual emptying will mainly be on gulper emptying technologies and mechanized emptying on cesspool emptying technologies since they are the most commonly used emptying methods in Kampala.

Time Scope

The research was conducted for 6 months from April to September 2024 as indicated in the workplan.

Geographical scope

The research will be conducted in Kampala mainly targeting cesspool, gulper entrepreneur companies and sole proprietors operating in Kampala District. The research will be limited to the operations of these technologies in Kampala.

1.5 Justification

Nearly 99% of greater Kampala’s population uses the on-site sanitation service which requires emptying at some point(McConville et al., 2022). This has increased the demand for emptying services both at household and institutional levels, which in turn raises the need to assess their technological and environmental sustainability.

1.6 Significance

The research is aimed at providing recommendations to stakeholders to improve and develop the necessary guidelines during the usage of these technologies across the sanitation service chain.

CHAPTER TWO

LITERATURE REVIEW

2.0 Literature review

2.1 Introduction

A Sanitation service system refers to the management of human excreta from the point of generation to disposal(CAWST, 2016). A sanitation service system is categorized into two sections, the off-site sanitation service where the excreta is conveyed away from the plot where it is generated through a sewer system, and on-site sanitation service is where human excreta is collected and stored or treated from the premises where its generated. On-site sanitation service technologies are designed to be emptied periodically.

2.2 Fecal sludge management

A Sanitation service or fecal sludge management refers to a sanitation service chain that is made up of six components that are, capture, Containment, emptying, transport, treatment, and safe re-use and disposal(UNICEF, 2020).

The capture stage is the first of a sanitation service chain and is the immediate point where human excreta is disposed. This can be a pit latrine, toilet, or a bucket. The second stage is the containment stage where human excreta is stored. This can be the pit of the latrine or a septic tank.

The third stage is emptying where the fecal sludge is extracted from where it is contained, the type of technology used at this stage of the sanitation service chain is hugely determined by the type of containment for example non-mechanized technologies will efficiently work with non-lined pit latrines compared to mechanized systems. The access and depth of the containment also influence the type of technology to be employed at this stage.

The fourth stage is the transportation of fecal sludge from where it is contained using vacuum trucks or buckets to the treatment plant which is the fifth stage. This is where the fecal sludge is treated for safe re-use and disposal either to the environment or used for resource recovery.

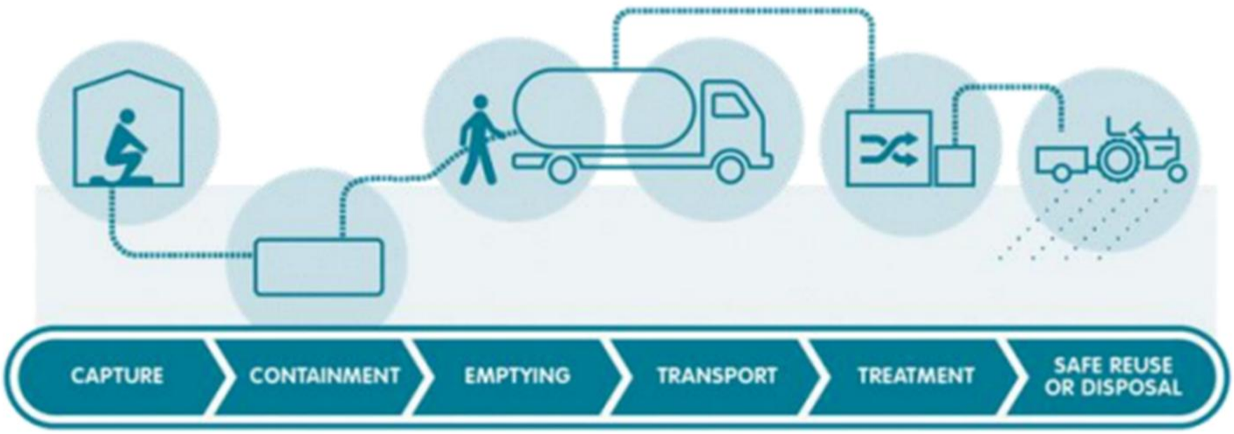

Figure 1 showing sanitation service chain, image by IRC-WASH

Fecal sludge management for onsite sanitation systems

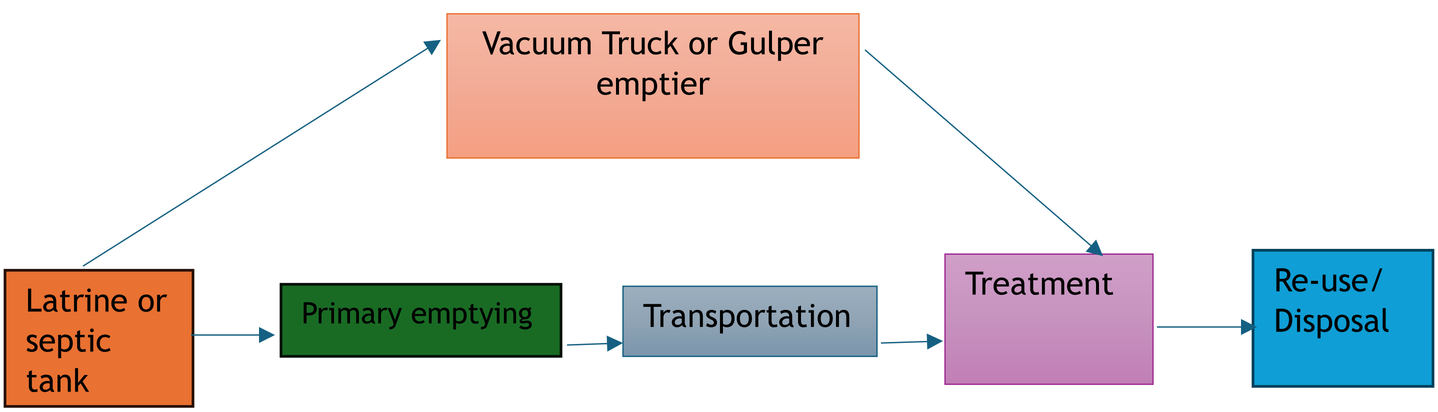

Figure 2 showing the onsite FSM sanitation system

2.3 Fecal sludge characteristics

Fecal sludge varies widely based on the sanitation technology used on site, and the fecal sludge storage duration depends on the filling rates and emptying frequencies.

The inflow, infiltration, and climate conditions contribute to the variability of fecal sludge characteristics(Strande et al., 2014).

Individual household habits also contribute to the variability of sludge characteristics, for example, dry versus flush toilets, and the type of anal cleansing materials used. The fecal sludge storage period influences the digestion process of the fecal sludge during storage(Strande et al., 2014).

2.4 Mechanized and non-mechanized technologies

On-site sanitation emptying technologies are categorized into two categories: manual emptying which comprises hand pumps, and mechanized emptying, which comprises a mechanized pump or vacuum track.

Mechanized systems

Mechanized systems offer a very efficient way of emptying and fecal sludge handling and are much safer and healthier for the service provider providing emptying services these are powered by electricity or fuel. However, mechanized systems also have limitations for example they cannot empty un-lined pit latrines, they are also limited by access with a distance consideration of 25 meters and the emptying depth of 2 to 3 meters(CAWST, 2016).

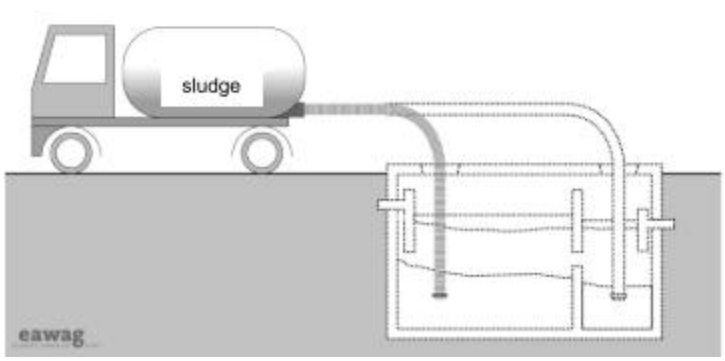

Figure 3 Cesspool emptier during operation(Tilley et al., 2008a)

Mechanized systems on the other hand also pose technological and environmental limitations for example some of the spare parts cannot sourced on local markets since most of these technologies are imported(CAWST, 2016). Spillage of the hose pipes poses an environmental and health risk because FS emptiers are usually exposed to a wide range of hazards while carrying out their work, and they do not usually have health insurance(Muoghalu et al., 2023). The common routes through which the pathogens get into the emptier's bodies are via hand-to-mouth contact (accidental ingestion), inhalation, and open cuts in the body. Infections from organisms found in FS have horrific effects for example neurological defects. FS emptiers are susceptible to sanitation-related diseases such as dysentery, cholera, diarrhea, hepatitis A, typhoid, and polio(Muoghalu et al., 2023).

The thickness of the fecal sludge also limits these systems. if the sludge is too thick, it might not be possible to have these technologies deliver the emptying service unless water is added which makes it more expensive compared to the manual emptying systems(Tilley et al., 2008a).

Non-mechanized systems

Non-mechanized systems on the other hand are the most commonly used emptying method in informal settlements, for example, the gulper technology. This is mainly because the sanitation facilities in these settings is mainly unlined pit latrines and access is very limited. 86% of the population in Kampala uses traditional pit latrines and only 7.6% have lined VIPs(KCCA, 2019).

Manual emptying is hard and unpleasant work which is despised by the majority of the population. However, several initiatives have been undertaken to improve manual or non-mechanized systems by introducing manually operated pumps to improve the efficiency of these emptying methodologies(CAWST, 2016) for example gulper emptying technology.

The manual emptying technologies pose a high risk of nasal, oral, and dermal exposure to pathogens to the personnel conducting the emptying activity(Strauss, 2005). They also pose high safety risks as the workers enter into pits to collect sludge, increase in environmental risks due to spillage while handling and transporting the sludge, its time-consuming depending on the sludge characteristics and the maximum emptying depth is 1.5m.

2.5 Other Manual emptying methods

i. Emptying using a shovel, rope, and a bucket

   This method is mainly applied in composting latrines and dehydrating latrines where the fecal sludge is too thick and solid for the gulper or cesspool technology suction effect(CAWST, 2016). This type of emptying is unpleasant and poses high health and environmental effects.

ii. Manual pit emptying technology(MAPET)

   The hand pump is human-powered and is connected to a vacuum tank which is mounted on the pushcart. When the hand pump is pressed air is sucked out of the vacuum tank and fecal sludge is sucked into the tank(Tilley et al., 2008a)

Fecal sludge management plays a very critical role in achieving safely managed sanitation and safeguarding public health. Fecal sludge management services are provided by a range of service providers both formal and informal, private sector, government authorities, and other local players in the sanitation sector. However, the fecal sludge emptying cost is always left for households to manage which demeans access to sanitation services and increases human exposure to fecal matter which threatens both the environment and public health.

2.6 Effects of fecal sludge on the environment and public health

The majority of households, institutions, and commercial buildings in Kampala rely on onsite sanitation. The onsite sanitation containments need to be emptied depending on how often they get full, the FS needs to be transported to the FS treatment plant, treated, and later disposed into the environment.

As the above-mentioned processes are ongoing, the environment and human health are susceptible to pollution and disease-causing microorganisms due to the existing gaps along the sanitation service chain.

Fecal sludge obtained from various on-site containments including septic tanks, pit latrines, and others, if it is not managed properly with lack of safe storage, emptying, and disposal due to leakages, spillages, and discharge in open drains it can have a risk impact on the environment and public health. Fecal sludge contains a large number of microorganisms, some of these microorganisms are pathogenic, and untreated FS can cause significant health risks to humans, either through direct contact or exposure for example causing diarrhea and other waterborne diseases and infections(Ayu & Sartika, 2020a).

Fecal sludge has the potential to contaminate both ground water and surface water if containments such as septic tanks and pit latrines are not well constructed and lined. This causes the presence of e-coli in water which is later consumed by the population causing waterborne disease outbreaks such as diarrhea and typhoid.

Once disposed of into the environment, it causes an increase in both the biological oxygen demand(BOD_5) and chemical oxygen demand(COD) which produce malodorous gases such as hydrogen sulphide and ammonia causing deterioration in the air and water quality and increase water treatment costs for drinking water in treatment plants in a quest to meet acceptable standards.

2.7 Conceptual framework

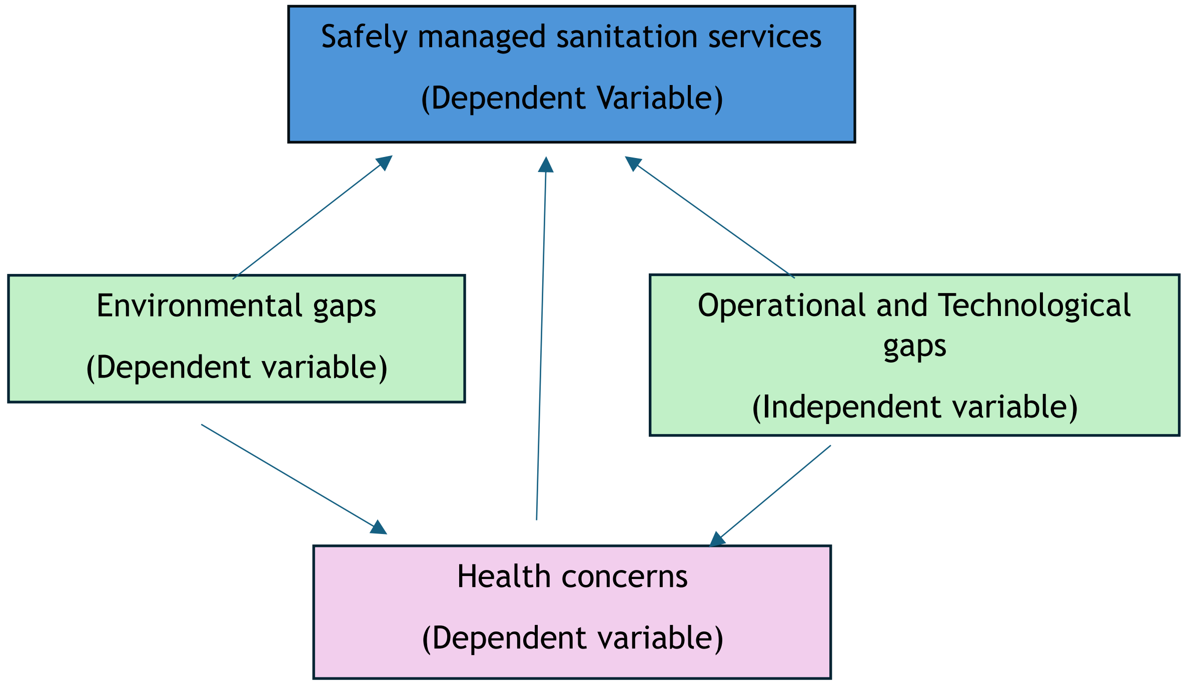

Figure 4 showing the conceptual framework

CHAPTER THREE

METHODOLOGY

3.1 Area of study

The research was conducted in Kampala mainly targeting cesspool and gulper entrepreneur companies and sole proprietors/individuals involved in the fecal sludge emptying business who dispose fecal sludge at Lubigi and Bugolobi wastewater treatment plant.

3.2 Sampling procedure

All samples were collected after a pit latrine and septic tank emptying event the cesspool emptying technologies. Samples were collected using equipment and materials like buckets, samplers, scoops, and disinfectants for cleaning and sanitizing purposes. waste components and 500 ml plastic containers for collection of samples for laboratory tests.

3.2.1 Parameters considered

- **pH**

  The pH analysis on septic tank sludge and pit latrine sludge samples was done using the digital pH meter.
- **TS**

  The total solids analysis in the septic and pit latrine sludge was done using the Oven & Weighing scale using APHA-2540B.
- **TVS**

  The moisture content and Total Volatile Solids (TVS) were obtained.TVS was determined by taking the weight difference between oven-dried solids and the 2-hr muffle furnace-ignited sample at 550ºC and expressed as a percentage of Total solids.
- **COD**

A COD teste was conducted. the spectrophotometer was set at an appropriate wavelength and the absorbance was read.

- **BOD_5**

  Three 300ml BOD bottles were used for each sample to allow full filling with no air space and provide an airtight seal. One bottle was filled with the pit latrine sludge and the other septic tank sludge. The third bottle was filled only with dilution water as a control or “blank”. A DO meter which is an electronic meter fitted with a specialized DO probe, was used to measure the initial dissolved oxygen concentration (mg/L) in each bottle. Each bottle was then placed into a dark incubator at 20°C for five days. 4. After five days, the DO meter was used again to measure the final dissolved oxygen concentration (mg/L). The final DO reading was then subtracted from the initial DO reading, resulting in the BOD concentration (mg/L).

- **Fecal coliforms**

  Fecal coliform analysis was done using a Filter membrane, sterile petri dish, incubator and microscope.

- **Helminth eggs**

Helminth eggs detection in both sludge samples was performed using Filter membrane, sterile petri dish, incubator, and Microscope to concentrate and visualize the eggs.

Objective 3: To identify improvements and best practices that can be adapted across the sanitation service chain to ensure safe fecal sludge management.

This was informed by results from objectives 1 and 2 to recommend appropriate improvements that can made on the various components of FS emptying technologies throughout the sanitation service chain and the factors that should be considered when selecting proper emptying and transport technologies in Kampala based on public health guidelines.

Data analysis

Data was collected using google forms and results from the research study were analyzed using Google Forms and Microsoft Excel.

3.3 Sources of Information and sample size determination

The sources of information were the cesspool, gulper technology companies and sole proprietors that are operating in the Kampala area.

The sample size was determined using the sample size calculator with a confidence interval of 95%, and a margin of error of 5%. The population size considered was the number of cesspools, gulper companies and sole proprietors operating in Kampala.

Sample size was calculated using the Taro Yemane formula

$n = N/(1 + N[e^2])$ where n is the sample size, N is the population size and e is the margin error.

The number(N) of cesspool and gulper technology operators in Kampala was obtained from Lubigi and Bugolobi wastewater treatment data on FS emptying operators that dispose off FS at the two plants.

3.4 Research Design

Objective 1: To examine the technological and operational gaps of fecal sludge emptying technologies.

Technological and operational gaps were assessed using information from the survey questionnaire that was developed with guidance from the technological applicability framework. The questionnaire captured technological experiences of fecal sludge emptying technology operators in Kampala

The data was collected and analyzed digitally using Google Forms and Microsoft excel.

Objective 2:To identify the environmental and health gaps of fecal sludge emptying technologies.

These were assessed using the survey questionnaire and results from the laboratory analysis of constituents of fecal sludge from pit latrine and septic tank containment to ascertain the difference in fecal sludge quality and the probable environmental effects and health issues associated with fecal sludge emptying. Since health risks are a function of the type and quantity of pathogens found in the FS sample, the design of the containment and individual behavior of the operators that is an attitude to risk and compliance to SOPs during operations(Muoghalu et al., 2023).

Both objectives 1 and 2 were assessed and informed by the laboratory results from the two fecal sludge samples that is the septage and pit latrine sludge. This is so because fecal sludge is characterized based on the type of containment were it is deposited and the time duration the fecal sludge stays in the containment.

3.5 Analysis of FS

For this research study fecal sludge characterization by containment type specifically considering sludge from the septic tank and pit latrine was considered. Seven fecal sludge parameters indicators were considered as indicated in the table below;

Table 1 Showing fecal sludge parameters analyzed

	Fecal sludge Indicator/parameter	Fecal sludge containment		Equipment
		Septic tank	Pit latrine	
1.	pH			Meter, Meter, APHA-4500-H+B
2.	TS(mg/L)			Oven & Weighing scale, APHA-2540B
3.	TVS(as % of TS)			Muffle furnace & Weighing scale,
4.	COD(mg/L)			Spectrophotometer, APHA-5220-2
5.	BOD_5(mg/L)			DO meter aerator and BOD incubator, APHA 5210-B
6.	Fecal coliforms(CFU/100mL)			Filter membrane-0.45µm, sterile petri dish, incubator, microscope
7.	Helminth eggs(Numbers/L)			Filter membrane, sterile petri dish, incubator, Microscope

N, the number of companies and individuals that are registered and deposit FS at Bugolobi and Lubigi wastewater treatment plant was 82

The sample size, n = 82/(1+ 82[e^2])

n = 82/1+0.205

n = 68

The sample size for the research study was 68.

The research questionnaire was administered to 68 respondents who are FS emptying operators in Kampala.

Figure 5 showing the 68 responses that were received in Google forms

Ethical considerations

Consent to share information was taken from the respondents by reading for them the first statement on the questionnaire indicated below and they had the right to say YES or NO.

"This research instrument is aimed at collecting data for a Master's degree at Uganda Christian University for a study entitled "Assessing the effectiveness of on-site fecal sludge emptying technologies in delivering safely managed sanitation services in

Kampala". The information given herein will be treated with absolute/utmost confidentiality for only academic purposes, so you are humbly requested to avail the information requested".

Link to questionnaire survey: https://forms.gle/BXDfTE2f2vs2JjK18

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This section presents results obtained from the survey questionnaire that was administered to the onsite emptying technology operators and the laboratory results after analysis of septic and pit latrine sludge as per the three objectives of the research study.

Objective one: To examine the technological and operational gaps of fecal sludge emptying technologies

Out of the 68 respondents that were interviewed, 64 were male and 4 were female

Figure 6 Administering questionnaires to onsite emptying technology operators and equipment used in the emptying process.

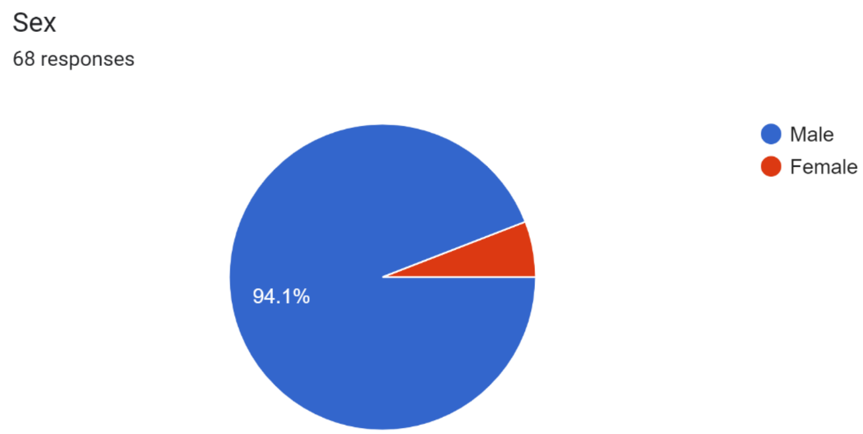

Figure 7 Showing the gender of respondents

From the research results, the majority of the onsite emptying technology operators conduct their emptying services in Kawempe division which is one of the five divisions of Kampala . This is mainly due to the fact that the division is near Lubigi wastewater treatment plant which receives FS from both cesspool and gulper operators compared to Bugolobi which receives FS from only cesspool emptiers.

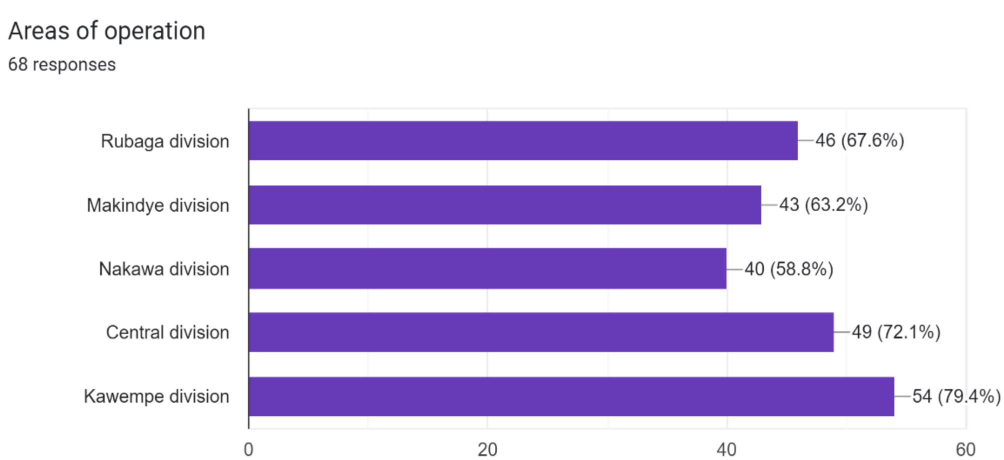

Figure 8 Showing areas of operation of fecal sludge emptying technology operators

Out of the 68 respondents that were interviewed, 25 offer emptying services using the gulper technology, 32 respondents offer emptying services using cesspool technology, 5 offer emptying services using both cesspool and gulper emptying technologies and 6 respondents shared that they use other technologies other than cesspool and gulper. The other technologies included manual, emptying using shovels, rakes, buckets and jerry cans, Pupu pump, Pitvaq, and Fludge camp emptying.

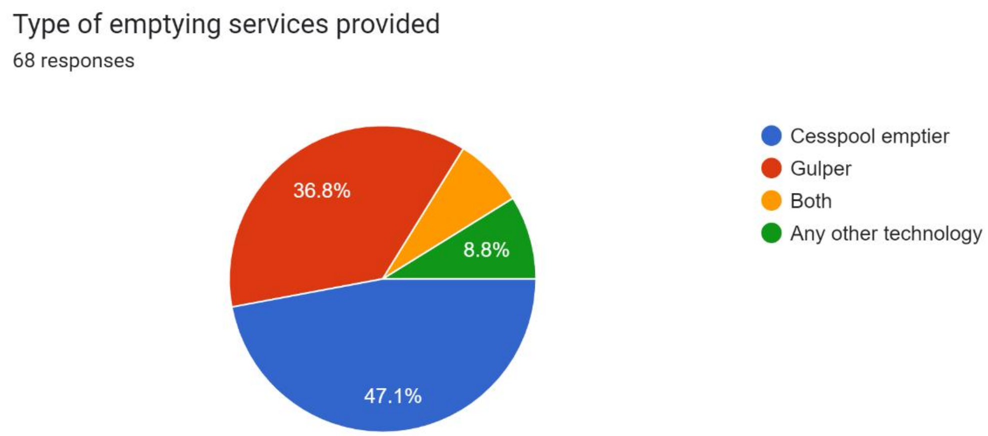

Figure 9 Showing distribution of technologies providing emptying services in Kampala

Results for most frequent clients that demand on-site emptying services

Clients were categorized into three and these included households, institutions focusing at schools, tertiary institutions and health care facilities and commercial/business entities.

Table 2 Showing demand distribution of emptying services in Kampala.

Onsite emptying technology				
		Client category		
		Households	Institutions	Commercial/business entities
1	Cesspool	32	12	12
2	Gulper	25	14	9
3	Other technologies	6	3	2

Results on the distribution of containments emptied by various technologies

Table 3 Showing distribution of emptied containments across emptying technologies

Onsite emptying technology					
		Containment type			
		Septic tank	VIP latrine	Pit latrine	Mobile toilet
1	Cesspool	29	20	12	3
2	Gulper	20	25	23	3
3	Other technologies	2	6	6	2

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The desludging depth, capacity and access were the parameters used to measure technological effectiveness of the cesspool and gulper technologies by comparing operational practice with the required standard.

Valley Zone in Makindye division, Salama road was considered semi-scope for analysis of the parameters.

Figure 10 Map showing semi scope area for analysis of parameters

Desludging depth

The sludge characteristic determined the desludging depth and the type of technology to be used. In instances were sludge was thick with solid waste, manual emptying was used using gulpers and additional shovels and buckets this led to breaking of containment slabs in some cases in order to dig out the fecal sludge.

Figure 11 Gulper operator inside the containment and usage of buckets to aid the emptying process.

Access

The width of the access route to the containment and the required length of the hose pipe, affected the effectiveness of the cesspool emptying technonlogy. For instances where the access route was less than 3 meters and the required hose pipe length was greater than 70 meters, the suction lift was low causing failure of the cesspool to empty sufficient amounts of the sludge as expected by the client unless for scenarios where the containment was above the cesspool and the emptying process was supported by gravitational force. The access parameter mainly affects cesspool emptiers, the manual emptying technologies are able to maneuver through the small walkways in valley zone up to the containment.

Figure 12 Hose pipes being coupled to improve on access to the containment.

Capacity.

The capacity of cesspools that were commonly used was 10,000 litres capacity. However, this should not be filled to capacity to avoid spillage challenges and over loading to give room for expansion while in motion and considering the status of Salama road that the trucks use. For gulper technology, Capacity was determined by the size of the drums, their number and the transportation means to be used to the plant.

Figure 13 Drums with FS loaded on a truck and a tricycle for transportation to the Lubigi FSTP.

During operations, the desludging frequency is influenced by the accumulation rate of the fecal sludge this was determined by the number of users for the contatinment and the usage behaviour of the containment users. For example users who dump solid waste in their containments had more desludging frequencies than those who manage containment usage well. The recommended desludging frequency is 3-5 years.

Figure 14 Wood being removed from a containment during emptying.

Table 4 showing technology operational practice Vs standard

Technology	Parameter							
	Access(m)	Standard	Desludging depth(m)		Standard		Capacity	Standard
			VIP latrine	Septic	VIP Latrine	Septic		
Cesspool		4 meters wide for access route. Hose pipe length 30m-50m(maximum)	1	3	5	5	10m3	3 -12m3
Gulper	At containment	At containment	2	3	3	3	It depends on the size of storage containers owned by the operator and the financial status of the owner. Drums are usually 240L	Determined by capacity of drums and transportation means.
Reference for standard:(Tilley et al., 2008b Ayu & Sartika, 2020b; Faecal Sludge Management in Rural Areas under SBM (G), n.d.)								

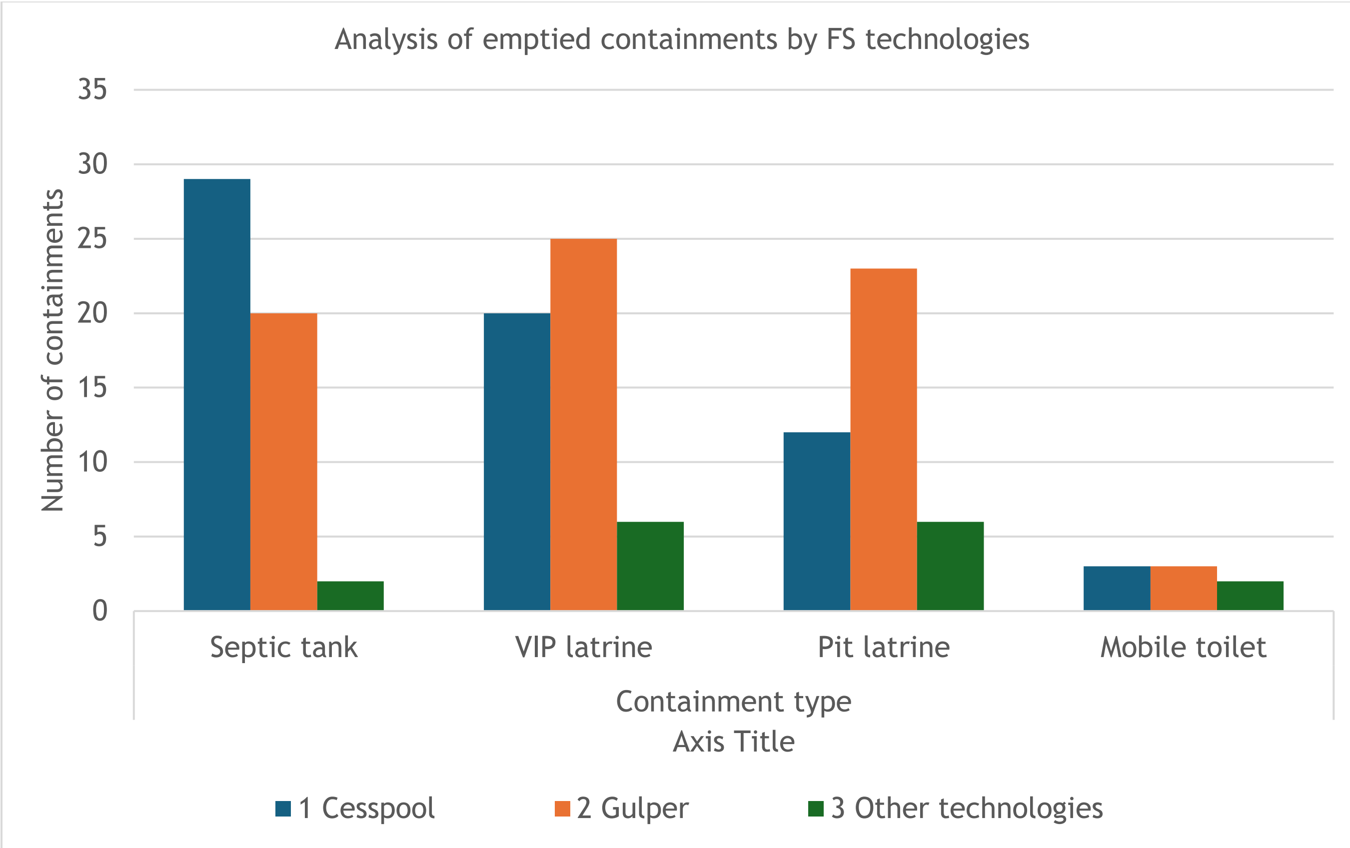

Figure 15 showing analysis of emptied containments by FS technologies

From the research findings, majority of the cesspool emptiers have a capacity of 10,000litres whereas Gulper emptying technology capacities ranged between 120 liters to 240 liters.

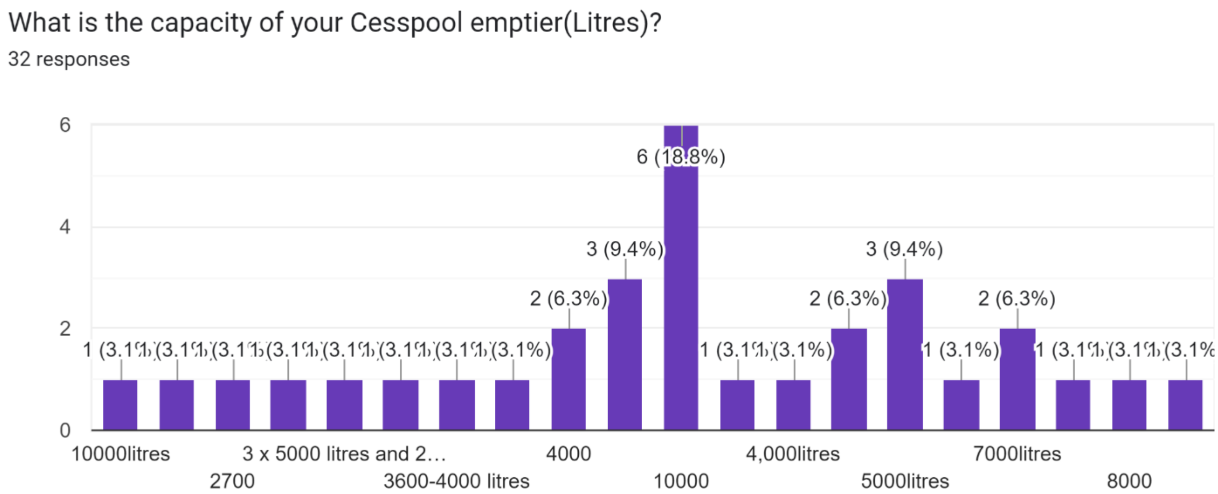

Figure 16 Showing emptying capacities of Cesspool emptiers

4.1 Results on desludging depth and emptying time of onsite emptying technologies

The majority of the cesspool emptying technology operators responded that the maximum desludging depth of their cesspools is 5m and for gulper technology operators it is 3 meters.

Time taken for emptying technologies to desludge standard containments that are 3 meter deep.

The time taken by different technologies to desludge standard containments is very key in ascertaining the effectiveness of the technology and the existing gaps leading to delays.

Table 5 Showing time taken to empty different containments by onsite emptying technologies

Containment	Time taken	
	More than 1 hr.	Less than 1 hr.
Cesspool		
Septic tank	1	31
VIP Latrine	8	16
Pit latrine	19	5
Gulpers		
Septic tank	11	11
VIP Latrine	19	4
Pit latrine	22	3
Other technology		
Septic tank	3	3
VIP Latrine	5	1
Pit Latrine	6	0

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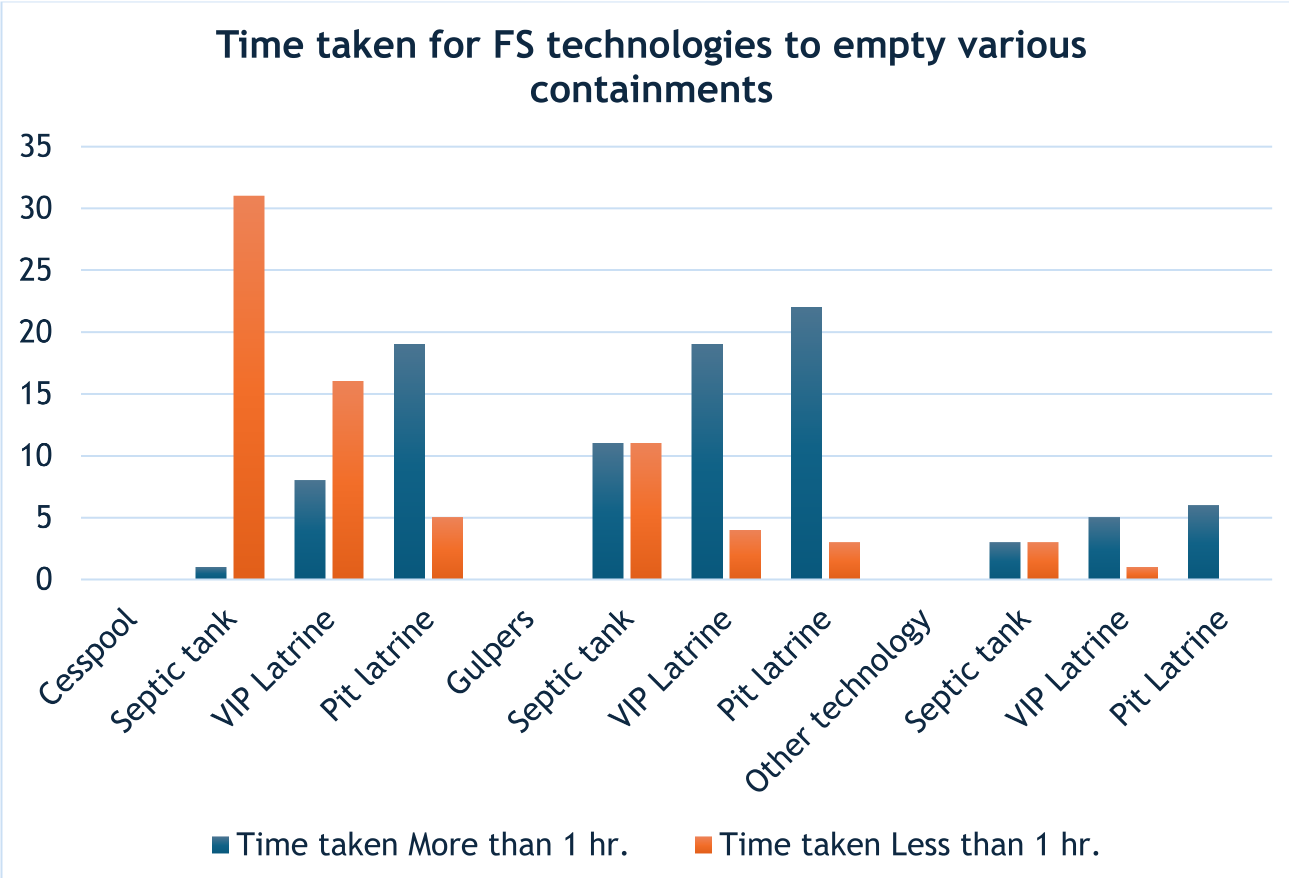

Figure 17 Showing time taken by emptying technologies to empty various containments

4.2 Containment emptying

Respondents were asked whether they fully empty their clients' containments and below are the results

Table 6 Showing number of onsite emptying technologies that fully empty clients containment

Do you fully empty the client's containment?	Number of respondents	
Cesspool		
Yes	18	
No	14	Why • Poor accessibility of containments especially in slums • High levels of solid waste in latrines • Some facilities are deeper than the desludging depth of the cesspool. • Some containments have thick sludge which affects the suction strength of the equipment. • Limited capacity of cesspool visa vi size of containment
Other technologies		
Yes	**2**	
No	**4**	Why • Limited capacity of the technologies to empty deep pits • Limited capacity of storage equipment ie drums and buckets.

Gulper		
Yes	6	
No	19	Why • Some pits are deeper than the desludging depth of the gulper equipment • Some pits have loose soils and these usually cave in during emptying. • Some households don't have funds to fully empty their containments Leading to partial emptying. • Limited number of drums available to store the fecal sludge.

4.3 Challenges encountered by onsite sanitation emptying technologies at the emptying and transportation stages of the sanitation service chain

Table 7 Showing challenges encountered by emptying technologies at various stages of the sanitation service chain

	Onsite emptying technology	**Challenge**	
		Emptying	Transportation •
1.	Cesspool	• Damages created on suction pipes • Pumps often break during this process leading to high fuel consumption • Damages on the tank due to	• transportation of fecal sludge. • Leakages due to porous tanks and poor roads • Disruption from traffic officers • Poor road networks which affect effective

		solid waste dumped in containments • Limited access to fecal sludge especially for deeper latrines • Limited access to containments by trucks due to poor physical planning in informal settlements. i • Solidification of fecal sludge which affects the suction effect of pipes during emptying • Unlined pit latrines usually cave in during the process due to suction strength of the cesspool. • Electric shocks due to poor electricity connections on some of the sites.	• Poor mechanical conditions of vacuum emptiers.	
2.	Gulper	• Blockages due to solid waste in pits. • Breakdown of the equipment during the emptying process. • Breakdown of suction pipe during this process. • Pit latrines usually collapse • Blockage of filters during emptying. • The suction effect depends on the energy of the operator	• Mechanical breakdown of motorcycle due to heavy load from drums • Poor roads which leads to leakages since drums are not covered tightly. • Criticism from	

		• Rusting of gulper equipment • Conflicts in the neighborhood since the emptying process is unpleasant. • Injuries since the process is manual. • The suction pipe is made up of low-grade plastic and it frequently crucks when it gets in contact with hard substances in the fecal sludge which causes leakage. • Electric shocks due to poor electricity connections on some of the sites.	other road users on fecal sludge transportation. • Disturbances from traffic officers. • The drums build pressure during transportation which causes the covers to go off, spillage which causes public nuisance especially when using tri-cycles	
3.	Any other	• Loose soils for unlined pit latrines • Solid waste which leads to break down of equipment	• Leakages due to weak storage materials • Poor road networks	

4.4 Results of Onsite sanitation emptying technology parts that frequently break down

Table 8 Showing results of technology parts that frequently break down

Onsite emptying technology		Part
1	Cesspool	• Hydraulic Pump • Suction hoHse Pipes • Propeller shafts • Oil seals • Tank • Pump valves • Pump seals which causes hydraulic fluid to mix with sludge.
2	Gulper	• Hooks • Gulper filters • Drums
3	Any other	• Buckets/drums • Ropes • Hydraulic pump • Jerrycans •

4.5 Spare parts availability on the market

Table 9 Showing spare parts availability on the market

	Onsite emptying technology	Spare parts availability		Why No?
		Yes	No	
1	Cesspool	22	9	• Vehicle models are old-below 2010 • It is very expensive to import spare parts which makes them scarce on the market.
2	Gulper	24	1	• Only the gulper emptiers association sells the spare parts.
3	Any other	6		

4.6 Other onsite emptying technologies available on the market

Respondents shared other onsite emptying technologies that are available on the market as listed below;

- Manual emptying using shovels, rakes, buckets and jerry cans
- Pupu pump
- Pitvaq
- Fludge camp emptying

Table 10 Showing response on why other on site emptying technologies are not commonly used.

Response from onsite emptying technology operators		Are they commonly used?		Why are they not commonly used?
		Yes	No	
1	Cesspool operators	7	14	• They are dangerous and illegal • They are time consuming • They are tiresome since some of them are manual. • Some have very small capacity and can only favor containments near the fecal sludge treatment plant.
2	Gulper	12	5	• They are very expensive.
3	Any other			

Objective 2:To identify the environmental risks and health concerns associated with fecal sludge emptying technologies

The objective was developed to ascertain the environmental and health risks that are associated with handling fecal sludge during emptying and transportation processes across the sanitation service chain.

4.7 Results on equipment used to store fecal sludge during transportation

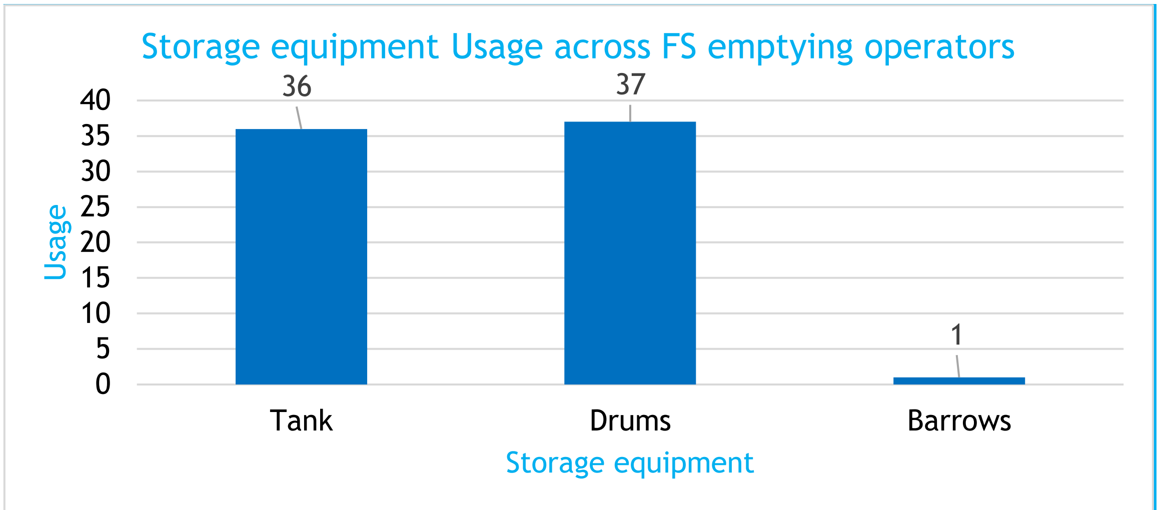

Figure 18 Showing storage equipment usage across FS emptying operators

Results on means of transporting fecal sludge to the treatment plant

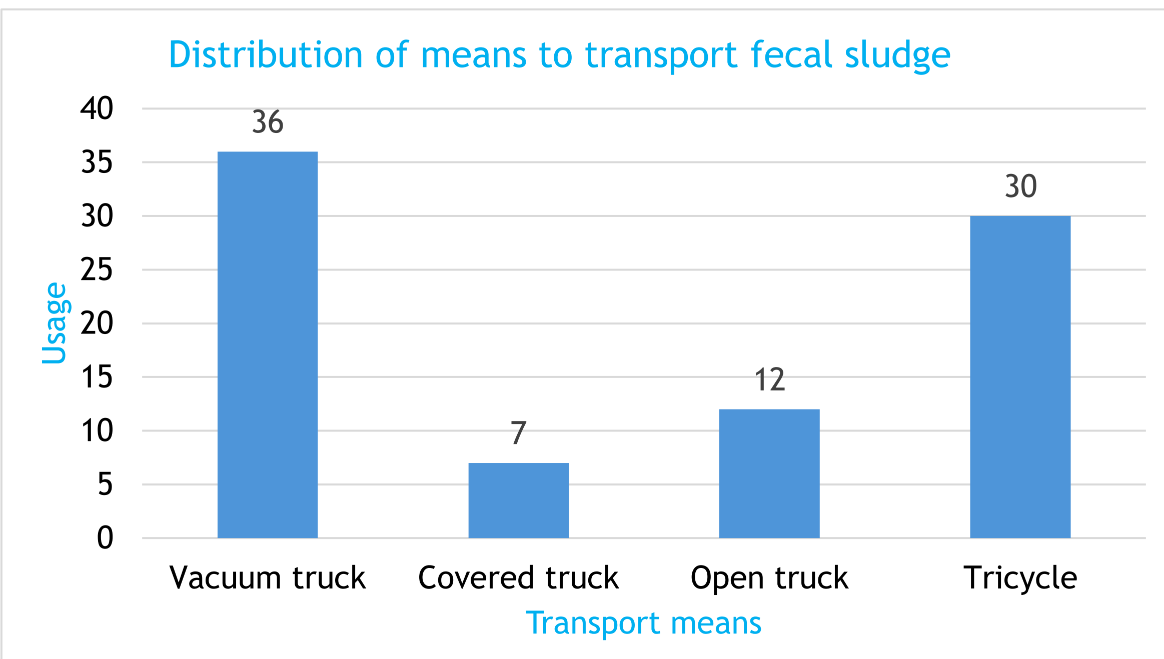

Figure 19 Showing usage of transport means across fecal sludge emptying operators

The cesspool operators shared that they transport FS using the vacuum track while the gulper and other technology operators shared that they use covered trucks, open trucks or tricycles to transport FS to the plant.

Respondents were interviewed on their adherence to wearing PPES, 63 operators responded YES, 1 operator responded NO and 4 responded sometimes.

4.8 Usage patterns of PPEs by FS emptying operators

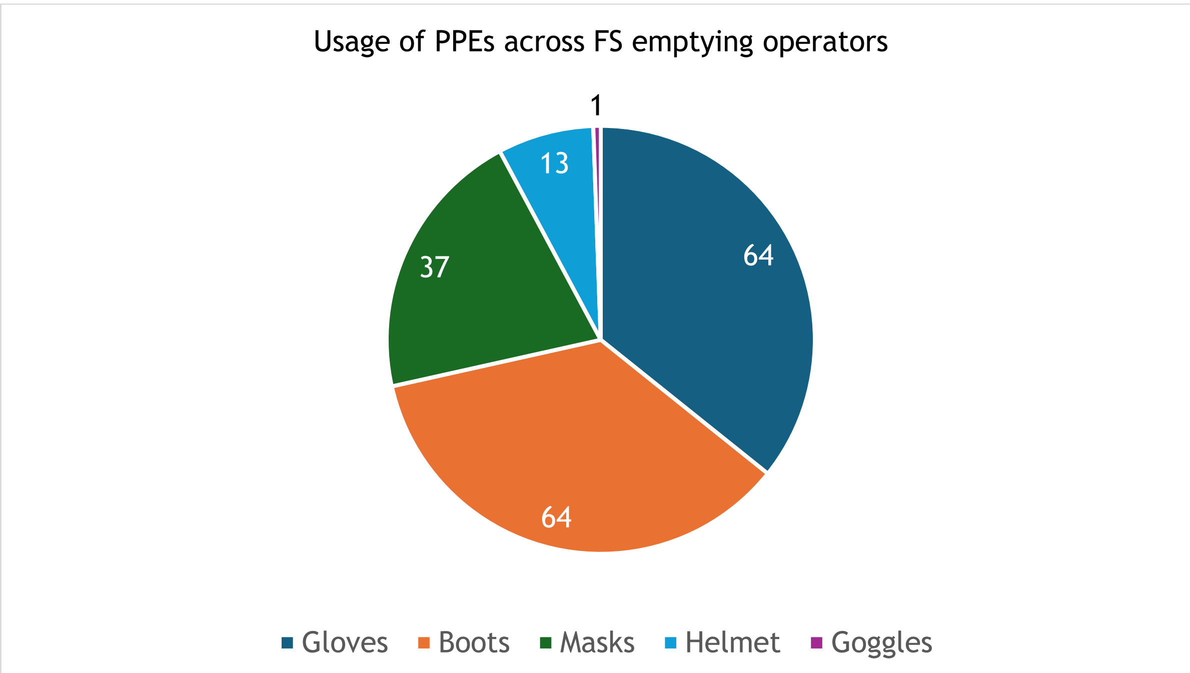

Figure 20 Showing usage patterns of PPEs by FS emptying operators

32 respondents shared that they have experienced health hiccups while operating in the fecal sludge emptying operations and 36 reported no injuries experienced so far.

Operators that have experienced health hiccups gave examples of illnesses and injuries that they have experienced during their operations as indicated below;

- Waterborne diseases such as typhoid, cholera, dysentery, Hepatitis A
- Infections such as skin and eye infections and Hepatitis B

- Suffocating due to strong, bad smell.
- Tetanus
- Headache due to the strong smell of fecal matter
- Fever
- Pneumonia
- Lung problems due to ammonia gas
- Stomachache due to the strong smell and chemicals used

The most frequent health problems reported were headaches, stomach aches, and typhoid.

53 out of 68 respondents reported that they had experienced physical injuries during their operation in the FS emptying business while 15 respondents reported that they had not experienced any physical injuries for example cuts, fractures, and dislocations.

4.8.1 presence of health insurance amongst FS emptying operators

64 0ut of 68 operators responded to the question regarding the availability of health insurance. 62 reported not having health insurance while 2 operators reported that they had health insurance.

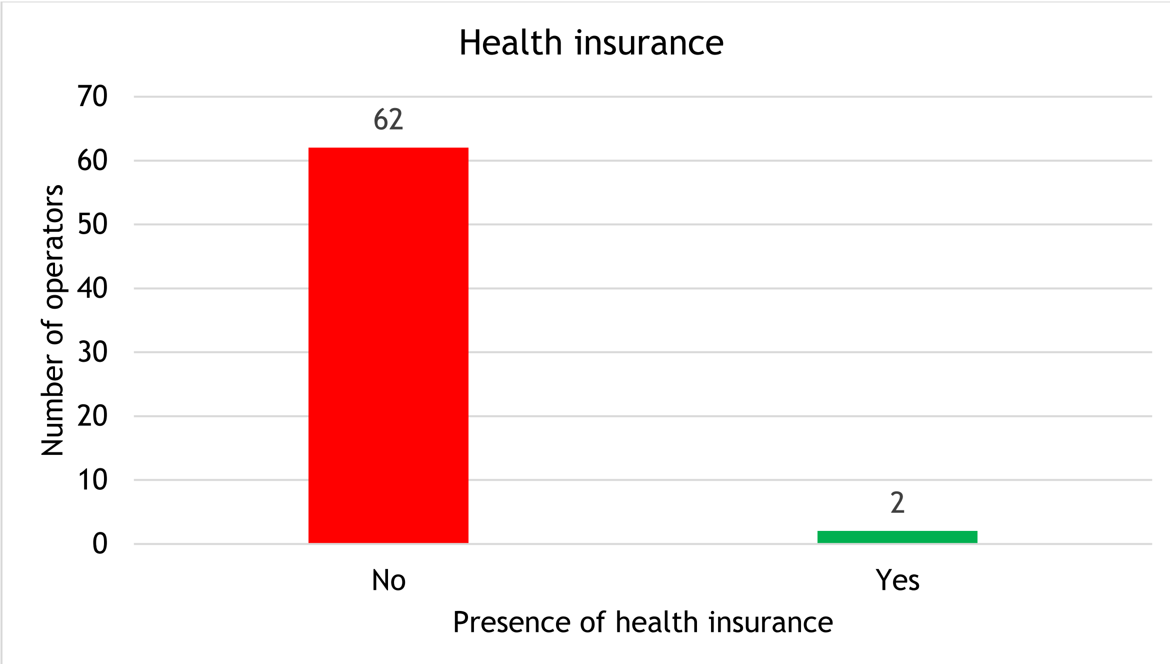

Figure 21 Showing availability of health insurance amongst FS emptying operators

54 out of 68 respondents responded that they had SOPs while 14 shared that they had no SOPs.

34 out of 68 respondents shared that they are permitted to dispose off fecal sludge in all FS treatment plants in Kampala while 34 responded that they are not allowed to dispose off FS in some of the treatment plants in Kampala and they gave the following reasons;

- It is only the Lubigi treatment plant with screens that can accommodate FS from the gulpers in Kampala because other treatment plants cannot separate sludge and other garbage.
- FS from gulpers has much solid waste which requires treatment plants that are designed to separate FS from solid waste.

67 respondents shared that there are seasons when disposal of FS is limited at the treatment plant mainly during operation and maintenance of the plant. They shared that there is always a provision of one inlet so that they are still able to dispose the

solid waste even when the plant is not fully operational, and this is always communicated beforehand.

Results on how FS emptying operators are regulated in Kampala

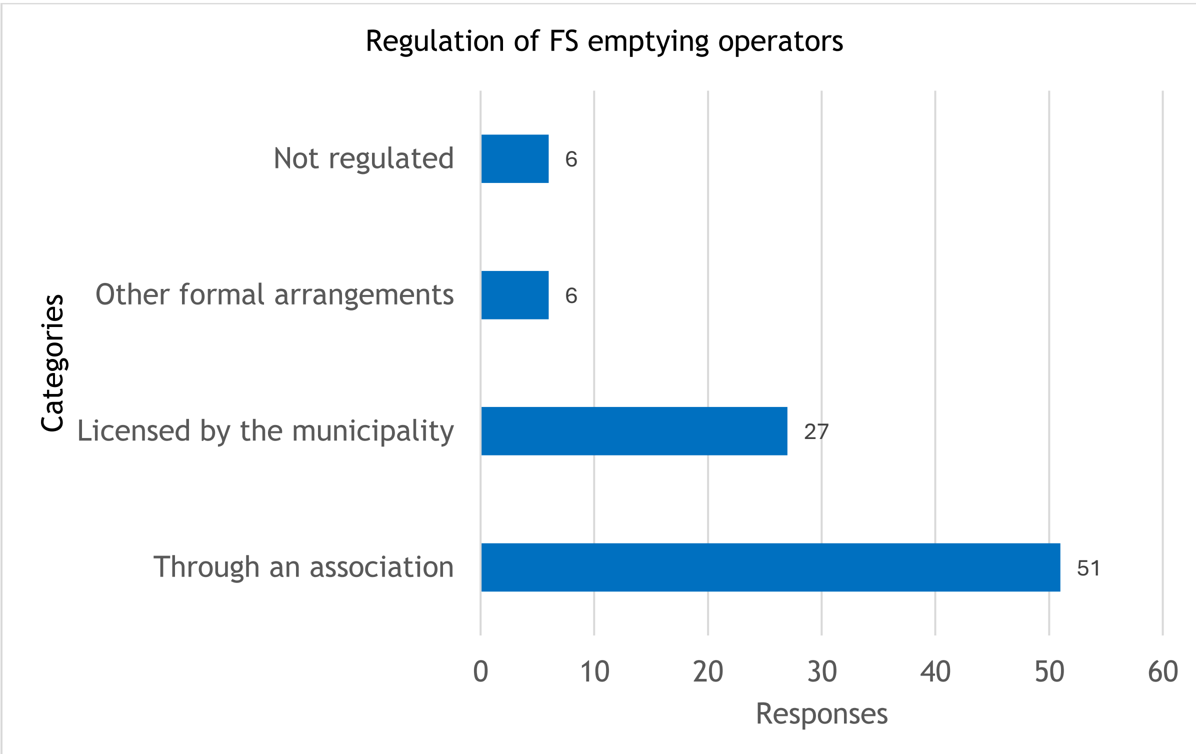

Figure 22 Showing regulation of FS emptying operators in Kampala

4.9 Discussion of laboratory analysis results

Table 11 showing laboratory results

	Fecal sludge Indicator/parameter	Fecal sludge containment			Equipment & Test method
		Septic tank	Pit latrine	Range	
1.	pH	7.66	7.31	5.0-8.5	Meter, APHA-4500-H+B
2.	TS(mg/L)	8464	15536		Oven & Weighing scale, APHA-2540B
3.	TVS(as % of TS)	52	62		Muffle furnace & Weighing scale
4.	COD(mg/L)	1678	4947	70	Spectrophotometer, APHA-5220-2
5.	BOD_5(mg/L)	671.20	1706.79	50	DO meter aerator and BOD incubator, APHA 5210-B
6.	Fecal coliforms(CFU/100mL)	80000	2360000	5000	Filter membrane, sterile petri dish, incubator, microscope
7.	Helminth eggs(Numbers/L)	0	1	<1	Filter membrane, sterile petri dish, incubator ,Microscope

- **pH**

  The pH of the pit latrine sample was at 7.31 and that of the septic tank sample at 7.66. all the Ph values lie within the recommended standards for disposal in public sewers. From the results, the pH value of the pit latrine sludge was lower than that of the septic tank due to the high number of hydrogen ion concentrations in the pit latrine sludge compared to the septic tank sludge.

- **Total solids**

  The TS in pit latrine sludge was at 15,536mg/L whereas the septic tank sludge sample has TS of 8,464 mg/L. The high levels of TS in pit latrine sludge are associated with the containment usage behavior of the pit latrine users. from the survey questionnaire, both gulper and cesspool operators shared that pit latrines in Kampala have high content of solid waste compared to septic tanks where users are restricted by the type of containment to dispose of solid waste for example anal cleansing materials. These can be compromised in the pit latrine while for toilets which are normally connected to the septic tank, users are often vigilant on the type of material disposed in the containment to avoid blockages. High levels of TS cause blockages during desludging processes by the FS emptying technologies. This leads to failure of both the technology and complete emptying of the containment.

- **Total volatile solids**

  The Total volatile solids in pit latrine sludge were 62% of the total solids whereas in Septic tank sludge, they were 52% of total solids. The concentration of total volatile solids in pit latrine sludge was higher compared to septic tank sludge, making pit latrine sludge stronger than septic tank sludge. Exposure to volatile solids can lead to diseases such as hypochromic anemia, headaches, loss of coordination and nausea, respiratory issues, central nervous system problems, and allergic skin reactions(Hssops, no date), as reported by the FS technology operators in the survey questionnaire.

- **Chemical Oxygen Demand**

  COD was analysed using a COD test. The test was is very critical in quantifying the number of oxidizable pollutants both (organic and inorganic) in fecal sludge. The COD of pit latrine sludge was 4,947mg/L whereas septic tank sludge had COD of 1,678mg/L. This indicated that the pit latrine sludge has more pollutants, approximately twice compared to septic tank sludge. Both containments had COD which was way higher than the recommended effluent standard of 70mg/L, making fecal sludge in both containments a high potential pollutant if not handled well during storage, emptying, transportation, and disposal. High levels of COD put the environment at a higher pollution risk and health risks to the technology operators.

- **Biological Oxygen Demand**

  BOD_5 represents the amount of dissolved oxygen(DO) consumed by aerobic bacteria growing in fecal sludge. The BOD_5 in the pit latrine sludge sample was at 1706.79mg/L whereas that of the septic tank sludge sample was at 671.20mg/L. Both septic and pit latrine sludge samples never met the effluent standard of 50mg/L. This indicates that both septic and pit latrine sludge require high amounts of dissolved oxygen. In poor handling, these can be both a public and environmental health nuisance.

- **Fecal coliforms**

  The pit latrine sludge sample had fecal coliforms of 2,360,000 CFU/100ml while septic tank sludge sample had 80,000 CFU/100ml. these results indicated that pit latrine sludge has more fecal coliforms compared to septic tank sludge putting gulper technology users at a higher health risk and high levels of environmental exposure to micro-organism pollutants such as Escherichia coli. this is so because most of the gulper technology operators in Kampala empty pit latrines and given the emptying methodology of this technology were spillages and leakages are very prominent, it puts the environment and public health at risk. Both septic and pit latrine sludge do not meet the recommended standards of 5,000 CFU/100ml putting both technology operators and the environment at risk. This calls for more stringent measures while handling FS from both containments.

- **Helminth eggs**

  The Helminth eggs results for pit latrine sludge was 1 in a 10Ml sample and for septic tank sludge, they were not found. The presence of helminth eggs in the pit latrine sludge is attributed to the strength of the sludge compared to that of the septic tank given the BOD and COD values. In pit latrine sludge these were higher creating a suitable environment that favors the growth and survival of helminths. Helminth eggs are the infective agents for the types of worms for example ascaris lumbricoides and Schistosoma mansoni causing worm diseases referred to as helminthiases and are contained in variable amounts in wastewater, sludge and excreta. This indicates that proper handling and adherence to PPEs by FS technology operators is very core to reduce on the risk and exposure to these disease-causing micro-organisms.

Figure 23 laboratory analysis of pit latrine and septic tank sludge samples

Figure 24 fecal sludge samples in the weighing balance and after they have been oven-dried.

Objective 3: To identify improvements and best practices that can be adapted across the sanitation service chain to ensure safe fecal sludge management.

The objective was aimed at identifying improvements that can be adopted in the FS emptying business across the sanitation service chain to achieve safely managed sanitation.

61 out of 68 respondents shared that they add water to fecal sludge during the emptying process and 7 respondents shared that they don’t add water.

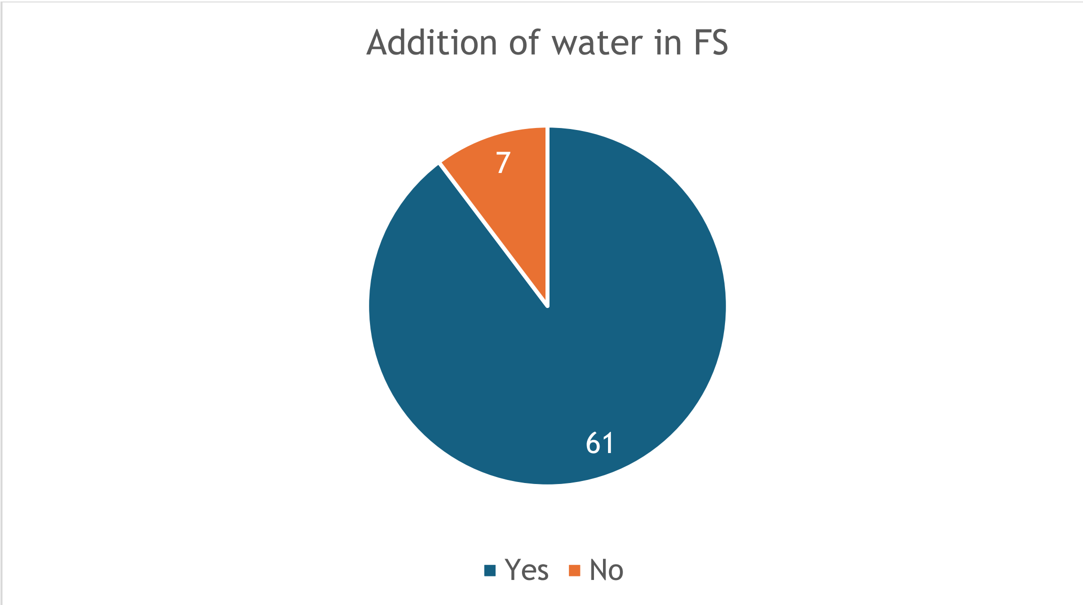

Figure 25 Showing the number of FS emptying operators that add water to FS during the emptying process

Respondents shared that the main reason why they add water is to soften the FS so that the equipment is not damaged but to also make the emptying process easier and faster on their side especially while emptying pit latrines.

FS emptying operators shared some of the improvements that can be made across the sanitation service chain in order to improve their operations so that safely managed sanitation can be achieved.

- Liaise with respective equipment suppliers while also ensuring proper usage and timely maintenance.
- Improvements in suction strength of pumps.
- Improvements on the gulper technology since it currently depends on manual strength.
- Improvement on the quality of tanks to reduce on leakage challenges during transportation.
- Liaise with respective stakeholders through engagements and lobbying. Also suppliers of the FS emptying technologies.

- Relevant authorities should construct more treatment plants in order to reduce distances moved by FS emptying operators.
- Explore all available means to negotiate with the necessary stakeholders in order to reduce operating costs since this causes some operators to dispose off sludge in open drains.
- All companies and sole proprietors in the FSM business should make sure that their operators are vaccinated from FS-related illnesses and KCCA should be active in enforcing this arrangement.
- Negotiating with relevant authorities to reduce tax charges which increases the cost of the emptying technologies, and this has driven many operators out of business yet the demand for emptying services is high.
- Support from relevant authorities for operators to acquire new models of FSTP Communities should be advised to construct lined pit latrines, these make the emptying process easier, cheaper, and environmentally friendly.
- The FS operator associations should increase engagements with NWSC and lobby for an Increase in the working hours of the FS treatment plant.
- Awareness creation on proper construction of septic tanks and emptying points on sites so that they are easily accessed by the emptying technologies this makes the technologies more effective at desludging.
- Operator associations should ensure that their members Observe SOPs and wear PPEs to avoid diseases that hinder work.
- Close supervision and enforcement of emptiers to make sure that they reach the plant this will stop the trend of some operators who discharge sludge in storm drains and swamps, especially at night.
- Concerted effort among the various stakeholders i.e. KCCA, NEMA, NWSC to simplify the procedure of acquiring licenses and involvement of the general public to be concerned about the environment.
- Through the emptier associations, operators can liaise with suppliers to avail good quality equipment and spare parts on the market

- FS treatment plants should increase the water supply at the plant to enhance cleaning of emptying equipment.
- Awareness creation in communities through barazas and meetings on the separation of solid waste so that its not dumped in the containments, especially pit latrines.

67 respondents shared what can be availed on the market by spare parts dealers to improve their operations.

- Pumps
- Suction hose pipes
- Valves
- Hydraulic seals

5.0 Discussions

Objective 1: To examine the technological and operational gaps of fecal sludge emptying technologies

Out of the 68 respondents, 32 offer emptying services using cesspools compared to the 25 that use gulpers, 5 offer both gulper and cesspool, and 6 use other technologies apart from the ones mentioned above. Emptying using a cesspool has more technological advantages, first and foremost the system uses a drainage pump which makes the suction of sludge less labor-intensive from the containment to the tank which is on top of the vacuum truck. The technology provides minimal contact between the operator and the fecal sludge which makes it more socially acceptable compared to the gulper technology.

The research results indicated that cesspool emptiers mainly empty septic tanks and VIP latrines with minimal emptying of unlined pit latrines whereas gulper technologies frequently empty VIP latrines and unlined pit latrines with minimal emptying of septic tanks. This is so because most pit latrines have thick sludge due to poor solid waste management at the household level which causes the breakdown of the suction hose pipe, the valves, and the pump of the cesspool emptier and some spare parts are not locally available on the market, secondly, unlined pit latrines usually capsize due to the vibration and suction effect caused by the pump during the emptying process, thirdly most of the unlined pit latrines are located in informal settlements with poor road networks to access the containment and this makes emptying very difficult and tedious.

It is not commercially viable for the cesspool operators and lastly, the technology cannot empty deep latrines beyond three meters since the desludging depth is directly affected by the suction lift of the pump and the distance between the vacuum truck and the containment (Tilley et al., 2008a).

On the other hand, gulper technologies are applied in emptying VIP and unlined pit latrines because the technology can reach containments in informal settlements where access is difficult for vacuum emptiers. The technology is also capable of handling more viscous sludge compared to the cesspool emptier, it can also empty unlined pit latrines since there are no vibrations and the suction force is minimal. The technology however has gaps that were identified through primary data collection and literature review. The technology is based on the manpower of the operator which directly affects the suction lift of the equipment hence its desludging depth(CAWST, 2016). The suction pipe is made from PVC which usually breaks when in contact with stones and other hard solid waste in the pit.

Gulper technologies are time-consuming while emptying containments reason being that their capacity is limited as regards both desludging and storage capacity. Research results show that gulpers use drums to store fecal sludge and these range between 120 to 240 liters which are minimal, the capacity therefore depends on the energy and the number of drums owned by the operator.

The technologies don’t often fully empty the client's containments since they are limited by the suction lift which affects the desludging depth, the storage capacity since some containments are bigger than the storage capacity of the containments, access to some containments is very hard due to poor housing and sometimes the sludge is very thick due to poor management of solid waste by institutions and households which affects the effectiveness of the technologies.

The research results indicated that the Hydraulic Pump, Suction hose pipes, Propeller shafts, Oil seals, and Pump valves which cause hydraulic fluid to mix with sludge are the parts that frequently break down on the cesspool emptier. For the gulper technology, it’s the hooks, suction pipes, gulper filters, and drums that frequently get damaged. The frequent break down of these parts is notable because of the following reasons;, oil seals often break down due to the overly gritty nature of sludge and constant friction between the seal and the shaft. This causes the seal to wear out much faster(Uk & Canbus, 2020). Suction pipes are frequently blocked and burst by thick sludge, especially in VIP and traditional pit latrines due to poor solid waste management by containment users. This has caused many cesspool operators to shy away from emptying latrines(WASTE, 2014). Faulty valves cause the sludge to recirculate with in the sump which causes the pump to use a lot of energy while carrying out desludging. This leads to high fuel consumption which directly affects the effectiveness of this technology and the operating costs.

For the gulper technologies, the suction pipe often breaks because of the quality of sludge, which is always thick and gritty, especially for pit latrines which are the most emptied containments by gulpers. This causes friction and cracks in the pipe which causes it to wear out so fast, this applies to the filters as well as the hooks.

Figure 26 Showing a gulper pipe and drums on the tricycle.

5.2 Objective 2: To identify the environmental risks and health concerns associated with fecal sludge emptying technologies

Along the fecal sludge management chain, health, occupational and environmental risks are high. These are worsened by the poor state of sanitation facilities in Kampala especially unlined pit latrines as reported by respondents. This objective was aimed at identifying the environment and health risks associated with fecal sludge emptying technologies across the sanitation service chain comprising of capturing, containment, emptying, transportation, and final disposal.

From the research, 36 respondents shared that they store fecal sludge in the tanks while 37 respondents store sludge in drums and transportation is mainly by vacuum trucks and tricycles. Tanks are secure compared to drums since they can contain the fecal sludge even when pressure builds up during transportation though these are also prone to leakages especially when a tank develops lines of weakness over time. Drums have a high susceptibility to leakages based on the experience of the operators who participated in this research.

As they transport the fecal sludge using drums and tricycles, pressure builds up which makes covers get off causing spillages during transportation. This not only creates public nuisance but pollution on both water and soil causing environmental and health concerns in communities for example fecal sludge ends up in surface water through runoff and groundwater through infiltration causing an increase in the concentration of disease-causing organisms, for example, e-coli affecting health and environment of immediate downstream populations and degradation of the environment.

The research results showed that only 34 out of the 68 operators that were interviewed are allowed to dispose off FS in all the FS plants in Kampala which limit access to disposal services hence increasing rates of non-compliance and causing some of the operations to dump fecal sludge in open drains, swamps, quarries, gardens and water bodies (KCCA, 2019).

Adherence to PPEs is still wanting. From the research findings, PPEs that are most adhered to are gloves and boots used by 64 out of the 68 respondents. The use of masks and helmets is still lacking, leading to some physical injuries. 53 out of 68 respondents reported physical injuries while operating the fecal sludge emptying technologies. Health hiccups that respondents frequently experience are headaches, stomach aches, and typhoid due to high levels of exposure to fecal sludge through dermal, nasal, and oral exposure to pathogens, for example bacteria, helminths, fecal coliforms, and others yet 62 out of 64 respondents that attempted this question are not under any form of health insurance.

Figure 27 Offloading and cleaning drums at the FS treatment plant in Lubigi-Kampala

Objective 3:To identify improvements and best practices that can be adapted across the sanitation service chainto ensure safe fecal sludge management.

This objective was aimed at identifying improvements that can be adapted by the sanitation emptying technologies across the entire sanitation service chain to enhance their operations in the diverse environments in Kampala along the entire sanitation service chain from containments to disposal units.

During the research, some improvements were identified based on the concerns of the FS emptying technology operators.

One of the limitations of the technologies is the inability to empty thick sludge. 61 out of 68 respondents shared that they added water to reduce the density/concentration of the sludge to enhance the effectiveness of the technology operations to save both time and limit the breakdown chances of the technology. The cesspool emptying technologies can adapt the use of pumps with a higher suction effect and introduction of air into the sludge to make it less dense for easy desludging. This will save the costs spent on water. The gulper technologies can adapt the use of HDPE pipes instead of PVC which frequently break due to solid waste and thick sludge.

Use of sensors on oil seals for the cesspool emptier pump as this alerts the operator to always conduct checks during the emptying process which will prevent the hydraulic oil from mixing with the fecal sludge which causes the pump to completely shut down.

The gulper technology is manual and currently relies on the energy of the operator. This limits the capacity of the equipment to empty fecal sludge, this can be modified by introducing a simple fuel-powered motor with a potable pump end that can suck the fecal sludge with minimal energy requirement from the operator.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

Challenges in FS emptying are diverse and complex across the entire sanitation service chain from capturing, containment, emptying, transportation, and final disposal. This creates gaps at various levels given the diverse environments that the technologies have to operate in. For example, different households and institutions in Kampala have different types of containments, access is a big challenge given the high rates of informal settlement developments due to poor urban planning.

FS treatment plants don't have disposal units for some technologies for example, the gulpers which have to dispose off FS with high solid waste content, even though they are the most commonly used in informal settlements where there is limited access to cesspool emptier technologies.

5.1 Conclusions

Technological and operational gaps identified

- The study assesses that semi-mechanization of the gulper technology so that it does not fully rely on the manpower of the operator will improve its effectiveness and demand on the market since it can access the hard-to-reach containments.

- The research study identified that the introduction of sensors on the oil seal to detect when it gets faulty so that the pump operations are immediately stopped can improve the lifetime of the pumps. This can improve the effectiveness of cesspool emptiers.

- The research assesses that the type of containments emptied by cesspool and gulper technologies varies with the former mainly emptying septic tanks and VIP latrines and the later mainly emptying VIPs and traditional pit latrines.

- The research assessed that both cesspool and gulper technologies spend more than one hour emptying pit latrines and this was mainly linked to the thickness of the sludge and solid waste which damages pipes and pumps as well as delaying the desludging process.

- 76% of Gulper technologies do not fully empty the client's containment and this is because most of the containments are deeper than the desludging depth of the equipment and some pit latrines have a high potential of caving in during the emptying process.

Environmental and health gaps identified

- The study assessed that the most common health encumbrance experienced by fecal sludge technology operators are headaches, stomachaches, and typhoid.

- The study discovered that 78% of the fecal sludge technology operators in Kampala have experienced physical injuries during their operation in this field, some of which are life-threatening.

- The study discovered that 97% of fecal sludge technology operators do not have health/medical insurance and this puts their lives at a higher risk while conducting their operations across the sanitation service chain.

- The study identified that pit latrine sludge wastewater parameters were higher compared to septic tank sludge. For example, the fecal coliforms, helminth eggs, Total solids, Total volatile solids, BOD_5, and COD were very high for pit latrine sludge compared to septic tank sludge as per the laboratory results.

Gaps where Improvements and best practices that can be adapted across the sanitation service chain to ensure safe fecal sludge management.

- Maintenance costs for cesspool emptiers/vacuum trucks are so high since the technology is imported and the available spare parts on the market are sub-standard, leading to high frequencies in the breakdown of the various components of the technology. This causes the resulting high emptying costs of the technology to be passed on to the end user, i.e. 250,000 Uganda Shillings for cesspool emptiers and 30,000 Uganda Shillings per drum for gulper technologies. This high cost acts as a serious deterrent or limitation to accessing safely managed sanitation services in Kampala.

- The research identified that solid waste management is critical and directly affects the effectiveness of onsite fecal sludge emptying technologies depending on factors including desludging depth, suction pressure, and emptying time, which if affected, reduces the number of trips per day resulting in reduced profitability and effectiveness of the technology.

5.2 Recommendations

For the technological, operational, environmental and health gaps identified

- The manufacturers should design technologies with the ability to completely and effectively empty a pit or septic tank with dry and liquid sludge. For example, the installation of pumps with stronger motors and suction pressure.

- The technologies should be designed so that they can access densely populated areas with narrow streets and poor roads, which are the characteristics of informal settlements in Kampala. This includes the installation of pumps with a high suction pressure and pipes that can run to the emptying point.

- Vaccination, medical insurance, and adherence to PPEs should be mandatory to all fecal sludge technology operators to reduce exposure to health risks.

- FS emptying technology operators should consider other more efficient methodologies of handling solid waste in FS containments, for example use of trash pumps these are designed to pump with hard and soft solids such as mud and sand to ease their operations and the emptying technology.

- FS emptying technology operators should consider conducting site reconnaissance before the emptying process to enable them plan better and reduce the time spent on site since containments vary in Kampala.

- Both technology operators should take precaution and adherence to SOPs while emptying, handling, transporting and disposing FS. This is so because both pi latrine and septic tank sludge wastewater parameters were way above the standards. However, gulper technology operators should take more precautions since their main emptied containments are pit latrines, whose wastewater parameters were higher than those of septic tank sludge as per the laboratory results.

Improvements and best practices that can be adapted across the sanitation service chain to ensure safe fecal sludge management.

- Management of solid waste at this level should be well handled through proper disposal other than disposing it in fecal containments. This is because it affects the desludging capacity of the emptying technology and increases costs on the client's end.

- Communal/ joint emptying by communities or households, promotes cost sharing of emptying services, especially in places that are hard to access especially informal settlements in Kampala. This can be a remedy for the high charges by the FS emptying operators, a catalyst for increased demand for emptying services hence keeping the FS emptying technologies in business.

- Fecal sludge emptying points or transfer stations for containments should be constructed in a way that they are accessible by the emptying technology to improve their effectiveness, especially the desludging process.

To WASH sector practitioners

- Dissemination and popularization of the Kampala Capital City Sewage and Fecal Sludge Management Ordinance, 2019 as a legal tool for effective management of fecal sludge in Kampala.

- Enforcement of KCCA public health guidelines for fecal sludge management which stipulates that all workers should be trained on the risks of working within the FSM system, including handling wastewater and/or fecal sludge, and be equipped to follow Standard Operating Procedures (SOPs); consistently and correctly wear Personal Equipment (PPE), have regular health checkups, receive medical advice and treatment, be dewormed and vaccinated. Only dedicated tools and equipment should be used, which are fit for the purpose.

- Installation of GPS equipment on all vacuum trucks and tricycles to track movement and ensure that the fecal sludge is only disposed at the fecal sludge treatment plant. This will improve the effectiveness of the emptying technologies across the entire sanitation service chain.

- Regular monitoring of fecal sludge emptying operations to ensure that all operators wear PPEs and comply with SOPs.

- Since both cesspool and gulper technologies spend a lot of time emptying pit latrines, it reduces the number of trips conducted by the operators. Authorities should consider extending the working hours of the plants beyond 8 am to 6 pm so that the operations of the technologies are increased.

- There should be appropriate points to accommodate the disposal of sludge by the gulper technologies at all fecal sludge treatment plants since the only plant that can accommodate them is Lubigi in Kampala. This will improve compliance with the disposal regulations.

- Encouraging usage of a combination of both cesspool and manual emptying especially in informal settlements ans in cases of thick sludge and presence of solid waste inorder to achieve satisfactory emptying effectiveness.

Recommendations for further research

- Based on the technological gap findings from the research study, further research should be made on modification of the gulper technology by including a motor and use of scooping methodology instead of vacuum to extract sludge so that it does not fully rely on the manpower of the operator.
- Further research on the introduction and use of air instead of water to reduce the density of the fecal sludge which is very costly.
- Further research on presence of helminth eggs presence in septic tank and pit latrine sludge and their perseverance to various wastewater treatment methodologies.

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Appendices

Survey questionnaire

Link to questionnaire survey: https://forms.gle/BXDfTE2f2vs2JjK18

Dear Respondents,

This research instrument is aimed at collecting data for a master's degree at Uganda Christian University for a study entitled ''Assessing the effectiveness of on-site fecal sludge emptying technologies in delivering safely managed sanitation services in Kampala''. The information given herein will be treated with absolute confidentiality for only academic purposes, so you are humbly requested to avail the information requested.

Introduction

1. Name of company/Individual?
2. Sex
    - Male
    - Female

3. Type of emptying services/technologies provided
    - Cesspool emptier
    - Gulper
    - Both
    - Any others which may be known or available

4. Number of vacuum trucks owned by the company/individual?
5. Number of gulpers owned by the company/Individual?

6. Areas of operation
    - Rubaga division
    - Makindye division
    - Nakawa division

- Central division
- Kawempe division

7. Who are your most frequent clients?
    - Households
    - Institutions
    - Commercial/business entities
8. What are the most emptied containments?
    - Septic tanks
    - Pit latrines
    - Mobile toilets

9. What is the average cost/rate charged for emptying
    - A standard pit latrine containment?
    - A standard septic tank containment?

Objective 1 : Examine the technological gaps of fecal sludge emptying technologies

1. What is the capacity of your emptying equipment
    - Gulper?
    - Cesspool?
    - Any other technology?

2. How much fecal sludge does your company dispose off at the wastewater treatment plant per day?
3. On average, how many containments do you empty per day?
    - Gulper

Pit latrine?

Septic tank?

- Cesspool

Pit latrine?

Septic tank?

- Any other technology

Pit latrine?

Septic tank?

4. What is the maximum desludging depth of your emptying equipment
   - Gulper?
   - Cesspool?
5. On average how much time does the desludging process take?
   - Gulper?

   Less than 1 hr

   More than 1 hr
   - Cesspool?

   Less than 1 hr

   More than 1 hr
   - Any other technology?

   Less than 1hr

   More than one hour
6. Do you fully empty your client's containment?
   - Yes
   - No

   If No, Why?
7. What common challenges does your equipment encounter during the emptying process

- Gulper? Why?
- Cesspool? Why?
- Any other technology? Why?

8. Which parts frequently break down during the emptying process
    - Gulper?
    - Cesspool?
    - Any other technology?
9. Are spare parts readily available on the market
    - Yes
    - No Why?

10. What common challenges are encountered during the transportation of fecal sludge?
    Gulper? Why?
    Cesspool? Why?
    Any other technology? Why?

10. Are there other emptying technologies available on the market?

    - Yes
    - No

11. If yes share example

12. Why are they not commonly used?

Objective 2 : Identify the environmental risks and health concerns associated with fecal sludge emptying technologies

1. What type of equipment do you use to store fecal sludge during transportation?

- Tank on cesspool emptier
- Drums

- Other? Specify?

2. What transport means do you use to transport the fecal sludge?

- Vacuum truck with a tank
- Open truck
- Covered truck
- Tricycle

3. When emptying and/or transporting the fecal sludge, do you wear any special clothes or equipment?

- Yes
- No
- Some times

4. What personal protective equipment is worn?

- Gloves
- Boots;
- Masks;
- Overalls
- Others (specify)?

5. Are there any health defects that you/fellow operators have experienced during your operation in the fecal sludge business?

- Yes
- No

If Yes, give example?

6. Are there any physical injuries that you/fellow operators have encountered during emptying operations?

- Yes
- No

6. Do you have health insurance?

- Yes
- No

Do you have SOPs?(Observation i.e. a copy of SOPs)

- Yes
- No

5. Are you permitted to dispose off fecal sludge in all fecal sludge treatment plants in Kampala? If not, why?

6. During the year are their periods when it is not possible to deliver to the treatment sites? If so, why?

7. How do authorities regulate your company?

- Through an association
- licensed by the municipality
- other formal arrangements
- not regulated
- I Don't know

Objective 3: Identify improvements that can be adapted by emptying technologies to ensure safe fecal sludge management.

1. Do you add water to the fecal sludge during emptying?

- Yes
- No

If Yes, why?

2. what are some of the improvements that can be made in the fecal sludge emptying business to increase the efficiency of fecal sludge emptying technologies

- Gulper?
- Cesspool?
- Any other technology

3. Suggest technological modifications that can be made to the technology to enable it to operate effectively.

- Gulper
- Cesspool
- Any other technology

4. suggest recommendations that can be adapted by the fecal sludge emptying technology operators to improve sanitation service delivery.

5. Suggest what can be availed by spare parts suppliers to improve the effectiveness of your operations.

Other questions

8. Any other challenges encountered during

- Emptying?
- Handling and transportation?
- Disposal at the wastewater treatment plant?

9. What are your recommendations for,

- Authorities?
- Technology suppliers?
- Wastewater treatment plant?
- Fellow emptier companies?

Thank you very much

3.4 Workplan

	Activity	Month-2024								
		Jan	Febr	March	April	May	June	July	August	Sept
1	Project identification									

2	Proposal concept development									
3	Oral presentation									
4	Mapping cesspool and gulper operators									
5	Data collection and field work									
6	Data Analysis									
7	Laboratory tests for fecal sludge constituents									
8	Research report compilation and finalisation									
9	Notice to submit research report for examination									

Table 2 showing research work plan

3.4 Budget

ITEM	DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
Mapping	Mapping cesspool and gulper emptiers operating in Kampala	20	20,000	400,000
Digital survey forms	Development of digital data collection survey forms	1	200,000	200,000

Data Collection	Research assistants	2	500,000	1,000,000
	Laboratory tests (fecal sludge sources-Septic tank and pit latrine)	2 samples	500,000	1,000,000
Communication	Internet and airtime	1	100,000	100,000
Logistics	Transport	1	200,000	200,000
SECRETARIAL WORK	Printing and Binding	3 copies	30,000	90,000
MISCELLENOUS		1	200,000	200,000
TOTAL				3190,000/=

Table 12 showing the research budget.

Laboratory results

Pit latrine containment

NATIONAL WATER & SEWERAGE CORPORATION
CENTRAL LABORATORY- Plot M11, Old Portbell Rd, Bugolobi
P.O BOX 7053 KAMPALA, Email: external.services@nwsc.co.ug
CERTIFICATE OF ANALYSIS

Client: Namale Caroline
Address: Kampala, Uganda
Sample Description: Pit Latrine
Received Date: 13.06.2024
Sampled By: Client's Staff
Sample Number : 50/1872/2024/C/B

Document No: NWSC/WQ/QF/21.2A
Invoice No:131/INV/2024/567_QUO

Parameters	Units	Test Results	National Standards for Waste Water	Test Method
B.O.D	mg/L	1706.79	50	APHA-5210-B
Bact: Faecal coliforms IDEXX	CFU/100mL	2300000	5000	Not Specified
COD	mg/L	4947	70	APHA - 5220-2
Helminth Eggs	No./L	1	-	Not Specified
pH (Physical-Chemical)	--	7.31	5.0 - 8.5	APHA- 4500-H+ B
Total Solids	mg/L	15536	Not Specified	APHA 2540B

Remarks:

Biology :The sample tested was non-compliant as per the National Standards for Effluent Discharge.
Chemistry :The wastewater sample tested was non-compliant with regard to BOD and COD but complied for other parameters as per the National Standards for Effluent Discharge.

AUTHORISED BY: Manager Central Labaratory Services...

APPROVED BY: Senior Manager Water Quality Management ....

**** The NWSC certificate of analysis by no means continues to permit to any person or company undertaking to conduct business. This report reflects results of the sample as received at the labaratory premises.*

NATIONAL WATER & SEWERAGE CORPORATION
ES
P.o. Box 7053 Kampala, Uganda
Tel:+256313315111 / 715
Email:external.services@nwsc.co.ug
REF. NO.
SIGN.
DATE
EXTERNAL SERVICES

Septic tank Containment

NATIONAL WATER & SEWERAGE CORPORATION
CENTRAL LABORATORY- Plot M11, Old Portbell Rd, Bugolobi
P.O BOX 7053 KAMPALA, Email: external.services@nwsc.co.ug

CERTIFICATE OF ANALYSIS

Client: Namale Caroline
Address: Kampala, Uganda
Sample Description: Septic Tank
Received Date: 13.06.2024
Sampled By: Client's Staff
Sample Number : 50/1873/2024/C/B

Document No: NWSC/WQ/QF/21.3A
Invoice No:131/INV/2024/567_OUO

Parameters	Units	Test Results	National Standards for Waste Water	Test Method
B.O.D	mg/L	671.20	50	APHA-5210-B
Bact: Faecal coliforms IDEXX	CFU/100mL	80000	5000	Not Specified
COD	mg/L	1678	70	APHA - 5220-2
Helminth Eggs	No./L *	0 *	*	Not Specified *
pH (Physical-Chemical)	--	7.66	5.0 - 8.5	APHA- 4500-H+ B
Total Solids	mg/L	8464	Not Specified	APHA-2540B

Remarks:

Biology :The sample tested was non-compliant as per the National Standards for Effluent Discharge.

Chemistry :The wastewater sample tested was non-compliant with regard to BOD and COD but complied for other parameters as per the National Standards for Effluent Discharge.

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