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Effects of Poor Solid Waste Management on Faecal Sludge Emptying, Treatment and Disposal Services in Lusaka

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ABSTRACT

High urbanization rates but deficient basic service provision facilities in Zambian towns presents major challenges for municipalities in the collection, recycling, treatment and disposal of increasing quantities of produced human waste. Due to lack of proper functional systems for the management of solid waste in some Peri-urban areas (PUAs) of the city, some solid waste is disposed in some sanitation containment systems. Existing solid waste management practices in most PUA's includes the throwing of waste in pit latrines. About 22 percent by weight of sludge emptied from latrines in Lusaka is solid waste. This solid waste possesses negative effects on efforts to improve sanitation access for people in PUA's; especially on the improvement of faecal sludge management (FSM) services from emptying to treatment and the end use or disposal of sludge products. This is because contained solid waste in sludge has made it difficult for pit-emptier's and treatment plant operators to effectively empty and treat pit latrine sludge respectively due to cumbersome tasks of separating the waste from the sludge. Therefore, current methods for pit emptying remain mostly manual. Field performance tests on three pit latrine emptying technologies tested in Lusaka showed that none of the current innovative technologies offer any advantage over the currently used manual emptying methods (i.e., the use of an elongated scoopers). The failure of innovative pit emptying machines in sludge emptying entails there is need for households to stop current practices of waste management through disposal in pit latrines, otherwise proper sanitation services shall not be attained at household levels especially where need for emptying is required. The study explores the effects that solid waste presents on sanitation especially in FSM interventions from sludge emptying, treatment, reuse and disposal and recommends measures for FSM to have successful outcomes in accessible, affordable, and hygienic service provision.

Keywords: Solid waste, sanitation, faecal sludge, peri-urban, emptying

INTRODUCTION

Waste can be defined as solids and liquids that are discarded as useless or unwanted and arise from human and animal activities [1]. And as waste is a universal consequence of most human activities, has a link to population, urbanization and affluence [2]; [3]; [4]. Most human activities generate a certain amount of solid waste hence making it inevitable by nature. Solid waste can be any garbage, refuse, or sludge and other discarded material, including solid or semisolids resulting from domestic, industrial, commercial, mining, and agricultural operations [5]; [6]. The composition of solid waste varies from country to country depending on the economic situation, industrial structure, waste management regulations and life style and the generation rates also tally according to conditions [7]. In solid waste, waste generated from households, shops, supermarkets, and open market places are termed as municipal waste and semi-solid waste can be described in the form of human excreta. Municipal waste is disposed either in landfills, open dumpsites or incinerators [8] and human excreta is either conveyed through centralized sewer systems or managed through decentralized containment and treatment systems. Most developing countries experience poor waste collection and management and this leads to indiscriminate dumping of the waste – negatively impacting public health [9]; [10].

With increasing population, prosperity and urbanization especially in developing countries, collection, recycling, treatment and disposal of increasing quantities of waste is a major challenge for municipalities. The upsurge in population, high urbanization rates, and economic development have resulted in increased human waste production henceforth overloading current waste management systems [11]. Waste generation in developing countries has been increasing enormously at an average annual rate of 8.96% [12]. To exasperate the condition, the waste sector in developing countries has not been able to provide adequate and sustainable waste management services to the citizens [13]. In African cities, the rapid urbanization rates imply a rapid accumulation of unwanted waste material [4] and poor sanitation conditions. Sanitation is defined as "the provision of facilities and services for the safe disposal of human urine and feces. It also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal [14].

In Zambia, about 40 percent of the population live in urban areas hence it is marked as one of the fastest urbanizing cities in Sub-Saharan Africa [15]. The rapid urbanization results in the formation of low-income settlements known as peri-urban areas (PUAs). They are characterized with inadequate access to water, sanitation and hygiene (WASH) services, poor quality of housing, overcrowding or high population density and insecure residential status. These areas account for the highest number of Zambia's urban population and form a major feature of the country's cities landscape [16]. The rapid increase of population has exerted pressure on infrastructure and this has resulted in many complex problems regarding settlement, solid and liquid waste management. Lusaka's (the capital city of Zambia) population is expected to grow by 4.9% per annum to reach approximately five million people by 2035. The generation of solid waste is on the rise in the city of Lusaka due to this rapid increase in population, changing life styles and popularity of fast foods and disposable utensils. Only a fraction of this generated solid waste is collected and disposed at designated sites. Despite the existence of various efforts on solid waste collection, still the quantity of solid waste collected is small compared to the solid waste generated. The remaining uncollected solid waste is managed on-site by households, left on the streets, at roadsides and/ or in drainages. Between

1996 and 2011, the annual average amount of solid waste increased from 220, 000 tons recorded to 530, 000 tons respectively, an increase of 141% [17]. Therefore, solid waste management has become a major concern for the city of Lusaka. The problem is not only in Lusaka but also in unplanned settlements in other Sub-Saharan cities like Dar-es-Salaam where, ineffective solid waste collection is contributed to by haphazard solid waste disposal highly contributing towards environmental pollution. Solid waste in urban areas is generated by domestic sources, street sweeping, hospitals, commercial and industrial activities [18]. The resulting effect is that the task of managing solid waste has become an enormous challenge for the institutions charged with the responsibility of solid waste management [19]. Limitations on solid waste service delivery are mostly affected by inter alia: financial constraints [20]; technical factors [21]; [22], inadequate service coverage and operational inefficiencies of services [23]; [21]. Others include unwillingness of the users to pay for the solid waste collection services [24]; [25] and poor infrastructures [21]; [7]. These reportages indicate that, due to these constraints most of the wastes generated within municipalities are inadequately collected and managed thereby causing a serious contribution to environmental deterioration and public health risks especially in the peri-urban areas and adjoining high density areas.

Improving access to sanitation is one of the most effective means to improve public health [10]. It is reported that only about 63.3 percent of Zambia's population in urban areas had access to acceptable sanitation [26]. To increase access to sanitation services for the residents of Lusaka, faecal sludge (FS) management services especially in the PUAs, have been under establishment since 2012 to service households using on-site sanitation (OSS). Although there are encouraging successes in Chazanga and Kanyama areas where faecal sludge management (FSM) services were first introduced in 2012, the FSM services have however been facing immerse challenges. The frequency of total sludge collection in terms of pit latrine and septic tanks emptying, treatment and disposal is so far not known, but it is unquestionably still low for the formal pit emptiers. The Lusaka Sanitation Mapping Assessment (LSMA) in 2018 established that only about 52% of the latrines are emptied when they fill up and owners of the housing units (landlords) are almost exclusively responsible for organizing the emptying while 46% are replaced or their contents emptied into pits dug adjacent to them. Therefore, the challenge of developing affordable, accessible and hygienic services to most of the poor is yet to be fully overcome. This study aims to show the consequences of poor solid waste management services on sanitation particularly on faecal sludge management (FSM) along the sanitation service chain in the city of Lusaka. It takes a particular focus on the types of sanitation facilities in the city and the effects of disposal of solid waste into sanitation facilities and how this affects sanitation service delivery in the emptying, treatment and disposal of faecal along the FSM service chain. It also explores challenges that SWM possess in the professionalization of FSM services and the subsequent hindrance to the promotion of public health by the improper management of solid waste at household level. It analyses challenges faced by pit emptiers and pit emptying equipment in pit latrine emptying, the challenges faced during the treatment of sludge into safe products at the treatment plant and the effects solid waste has on treated and processed sludge products on their end use or in disposal processes. The specific objectives in the research are to quantify the average amount of solid waste that is found in sludge pits during emptying of faecal sludge; evaluate sludge emptying technologies which can operate effectively with the current conditions and quantities of solid waste in pit latrines in

Lusaka; and it provides recommendations on an alternative solid waste management method to avoid solid waste being dumped in the sanitation facilities.

METHODS

Study Sites

The case study area is Lusaka city, the capital of Zambia which has a total surface area of 360km^2 with an average population density of 7,017 people/km^2 [27]. Lusaka is sited on a flat plateau with a mild slope as low as 0.2%. Consequently, most areas of the city experience localized but often extensive flooding during the rainy season. Rocks underlying the City of Lusaka consist of schists interbedded with quartzite's and dominated by thick and extensive sequences of marbles (Lusaka Dolomites or Lusaka Limestone). The Lusaka dolomite consists of an integrated and well-developed system of conduits and solution channels. Most of the City also lacks artificial drainage systems hence in times of heavy rainfall, severe localized flooding occurs which results in disruption of access to social services, property damage, increased vulnerability to disease outbreaks and even loss of life [28]. The city has about 33 peri-urban areas and these peri-urban areas have little access to adequate sanitation services as well as have poorly developed public health infrastructure. About 90 percent of peri-urban households use pit latrines for their wastewater sanitation needs. Most of pits in these areas can be classified as "unimproved" according to the Joint Monitoring Program's sanitation ladder [29]; [28]. The other 10 percent of peri-urban residents use septic tanks, or cesspools and in some densely populated areas there are isolated cases of open defecation (estimated at 1-2 percent) [30]; [28]. in addition, 60 percent of Lusaka's water supply is derived from fairly shallow groundwater abstracted within the city, which is prone to contamination through fissures in the underlying rock [28]. This leads to deadly breakouts of water-borne diseases such as cholera and typhoid, which results in thousands of infections and hundreds of deaths [31].

The study was done in four out of the 33 PUAs of Lusaka namely Chazanga, George, Chawama, and Kanyama. The four PUA's were chosen for the study as they entirely rely on on-site sanitation and have had access to established FSM services the inception of services in the city in 2012 [32]. In all the four PUAs, SWM services are provided by Community Based Enterprises (CBEs) – these are individuals or a group of individuals engaged by the city council's waste management unit to collect waste from households to a central's location for transportation to the dumpsite by private companies [33]. However, due to failures by the engaged CBEs to provide adequate services to some low-income neighborhoods, informal sanitation service providers often fill the gap in service provision particularly for pit emptying.

- Chazanga is a peri-urban unplanned settlement located about 7.5 km north of the city center. Chazanga covers an estimated area 24 km^2, with a population density of approximately 9,361 people/ km^2 with an average sharing of 15 people per single pit latrine facility [34]. Chazanga is a mixture of big smallholding/farm plots in the north and typical high density shanty compound properties in the south. The high property development occurs in the northern part where there is bare land. Chazanga Water Trust is mandated to provide water and sanitation services to Chazanga. The Trust operates a number of boreholes located within the areas. Chazanga Water Trust operate a Faecal Sludge Management (FSM) facility which used to receive and treat faecal sludge from pit latrines. The facility however is none functional due to inadequacy and maintenance challenges. The pit emptying services are run by the Water Trust.

- George is a peri-urban settlement located 13 kilometres north-west of the city centre. George PUA covers an estimated area of 2.05 km^2, with a population density of approximately 31,000 people/ km2 [34]. It is a peri-urban sprawl of substandard housing units. Most residents of George Compound depend on pit latrines for faecal containment with most poorly built and shared by households. There are a few VIP and flush toilets connected to individual septic tanks. Some parts of the settlement are water-logged and in turn regular flooding is experienced during the rainy season. This situation causes pit latrines to overflow, emptying their contents to road drains and water sources, thereby causing serious health and environmental problems. Flooding also causes pit latrines and houses to collapse. Water supply to the area is provided by LWSC through stand taps and water kiosks with a few individual connections. At the time of the study, there were no formal providers for FSM services in the area.
- Chawama is a peri-urban settlement located about four (4) kilometres south of the city centre. Chawama covers an estimated area of 4.08 km2, with a population density of approximately 30,984 people/ km^2 [34]. The houses in Chawama are arranged into sections with passable roads in between. However, the structures are generally poorly built. They are very close to each other and some share sanitation facilities. Most people in Chawama use pit latrines for faecal sanitation. Only few houses have septic tanks. Most of the pit latrines are shared by a number of households, and hence fill up fairly quickly. The area is subject to flooding during the rainy season due to poor or non-existent drainage infrastructure and poorly drained soils. The flooding often leads to contents of toilets being washed away into natural ground and surface water courses, leading to outbreaks of waterborne diseases such as cholera and dysentery. Water Supply to the area is provided by LWSC through stand taps and water kiosks with a few individual connections. At the time of the study, there were no formal providers for FSM services in the area.
- Kanyama is located on the western side of Lusaka city center, approximately 7km from the central business district (CBD). Kanyama covers an estimated area of 14.25 square kilometers, with a population density of approximately 13,800 people/ squared kilometer [34]. It is the biggest, most highly built and densely populated PUA in Lusaka as its residents are primarily migrants from the rural areas coming to seek for employment opportunities in the city. Kanyama sits on Lusaka city's main aquifer and the aspect of its predominant reliance on on-site sanitation threatens the safety of water resources [28]. The PUA has Kanyama Water Trust (KWT) which provides water supply and FSM services to the residents offering sludge empting services in the area and its surrounding communities, under a delegated management contract with LWSC. It is the first PUA were LWSC introduced FSM services in 2012 [32].

Some of the other peri-urban areas were secluded out of the study as they have wastewater sewer line implementation projects underway and some are ear-marked for installation of sewer systems in the nearest future. Therefore, toilet mapping for improved on-site sanitation service provision in these areas was not necessary as residents will connect to the sewer system and the pit latrines will be decommissioned and on-site sanitation service provision will not be offered.

CASE STUDY APPROACH

This study adopts the case study approach through investigating the type of sanitation facilities mostly used by inhabitants in four PUAs of the city, the predominant methods of solid waste management practices occurring in the PUA's and measuring the solid waste ending in sanitation containment facilities by measuring the solid waste content in faecal sludge emptied from households which have requested and paid for sludge to be emptied from their containment facilities. The study was done through systematic and random methods dictated by activities in the Lusaka Sanitation Project (LSP) and the corresponding support provided by the GIZ Climate Friendly Sanitation (GIZ-CFS) program in PUAs of Lusaka. The activities included mapping of on-site sanitation facilities, survey questionnaires covering Knowledge, Attitudes and Practices (KAP) on OSS facilities and solid waste management in 10,003 households in three out of the four PUAs in the study and field tests on pit emptying equipment's innovated for challenging conditions, such as the presence of solid waste in pit latrines in all the four PUA's. Pit emptying studies concentrated on selected on the basis of the households requiring pit emptying services from pit emptying teams in the areas of operations. Before emptying, the pits were assessed in terms of structure stability for the emptying activities as pits sometimes collapse during emptying services. Each sanitation facility was assessed in terms of superstructure stability during the emptying exercise and period the equipment and the team were scheduled to be in the city, hence the number of pits varied from one equipment to the other. Semi-formal questionnaires on experiences with solid waste from pit latrines and its effects on pit emptying, operations and maintenance (O&M) of sludge treatment plants and related expenses were conducted with the Lusaka pit emptying teams and finally, recommendations were drawn for efficient and effective management of faecal sludge services in relation to solid waste were drawn from the pit emptying equipment innovators, pit emptiers and faecal sludge treatment plant managers.

DATA COLLECTION

Household Sanitation Mapping and KAP Study

In March to June of 2017, Water and Sanitation for the Urban Poor (WSUP) developed an electronic database of toilets in Kanyama to enable ownership, location, quality and emptying history of local pit latrines and septic tanks in one place. The aim of the concept for a toilet database was to provide an electronic database which could be used to monitor and predict pit latrine upgrades; and FSM service demand, enabling pit emptying businesses and toilet construction companies to improve their customer targeting. The database was populated using data from a sanitation mapping process. Data was collected through a combination of structured questionnaires (recorded on mobile tablets programmed with mWater software), observation and image capture. Questionnaires recorded the location of the toilet, key demographic information and the status of the facility [35]. In June, 2018, GIZ CFS extended the program and conducted the sanitation facilities mapping and KAP study in three peri-urban areas of Lusaka namely Chazanga on the North, Chawama on the South and George compound on the Western part of the City of Lusaka. All OSS facilities in households in the planned areas were targeted to take part in the mapping exercise but only consented households were meant to be interviewed for the KAP's. The main objective of the toilet mapping exercise was to collect specific data (attributes) on (of) household toilets including toilet age, construction materials including reinforcement type, roof type, flush type, mason, and sludge containment facilities in the project areas. Survey questionnaires were used in the KAP study and the questions sought to collect data on the solid waste handling and disposal practices of households in the three mentioned peri-urban areas, solid waste collection frequency by waste collectors, cost of solid waste collection and disposal services and a description of the service providers. The mapping of the facilities and features was done using questionnaires as data collection tools. The questionnaires were coded and loaded onto hand held data collection devices and the collection was done using a mobile mapping and data collection application TruField. TruField is a data collection application that launches directly from OpenDataKit (ODK) – an open-source software for collecting, managing, and using data in resource-constrained environments. The application allows both online and offline base maps that are used for location and also collecting data at the exact feature. The application also allows field papers to be embedded directly. TruField data application collects survey questions which are geo-tagged with a point or polygon. To improve locational accuracy, georeferenced and digitized base maps were loaded in the mapping application. This eliminated positional errors by combining GPS positioning capabilities of the handheld GPS with visual observation of the feature being mapped (on the basemap) so that the mapped feature is placed at the exact location. All the base maps used were georeferenced to Arc 1950, the coordinate and datum system suitable for use in Zambia.

The data collected during the mapping exercise included location coordinate of sanitation facilities, type of facility, features of the facility, number of users, owner contact details, and information on operations and maintenance of the sanitation facility. In addition, water points, solid-waste dump sites, educational facilities health facilities and commercial places were also mapped to supplement the toilet data [34]. The idea was to pick all the relevant features required to create thematic maps that, not only depict the sanitation facilities, but also the spatial characteristics of the project areas. This data is intended for use by many stakeholders in the sanitation sub-sector, including public service providers (LWSC, Council, and Water Trusts etc.), regulators (NWASCO, Ministry of Water Development, Sanitation and Environmental Protection etc.) and private service providers (Vacuum Tanker operator etc) [34]. For the purpose of this research, the mapping of toilets, water points and solid waste dumping sites was used and is summarized in Table 1 below. The total number of facilities mapped in all the project areas was 29,650 with 23,125 being toilets; 6147 water points while the solid waste dump sites were 378. The mapping was done with four (4) teams – a team per PUA. The number of enumerators per team differed among the areas depending on the size of the area. The Chazanga team had twelve (12) enumerators, the George team had 6 enumerators, while the Chawama Team had thirteen (13) enumerators. The total number of enumerators was 31. Each area was divided into sizable sub-areas equal in number to the number of enumerators in the team. Each enumerator was assigned a distinct area and asked to map all the toilets in that particular area. The location data processing was done using a combination of different software including QGIS, ArcGIS and OpenStreetMap.

Table 1: Mapped Facilities studied on OSS in three per-urban compounds of Lusaka

Area	Chawama	Chazanga	George	Total
Household Sanitation Facilities	5,927	13,189	4,009	23,125
Community Water Points	1,227	4,101	819	6,147
Solid Waste Disposal Sites	103	116	159	378
Total number of mapped facilities	7,257	17,406	4,987	29,650

There were 10,003 household respondents who took part in the KAP with the total number of respondents on KAP's per area being: Chawama 4,054 (40.53%), Chazanga 4,133 (41.32%) and George 1,816 (18.15%).

The KAP study/ baseline survey used qualitative data collection methods through which primary and secondary data were collected. A descriptive cross-sectional design was used for this survey, which aimed at determining the residents' sanitation and hygiene knowledge, attitudes and practices of use, emptying, disposal and upgrade at a specific point in time. A questionnaire with closed ended questions that had multiple choices was administered and responses recorded electronically using tablets. The questionnaire was divided into sections including: household demographic and socio-economic data, sanitation and hygiene practices, solid waste collection and disposal methods, and service providers. The questionnaire was written in English and translated by data collectors into the appropriate local languages and responses were noted in English. Primary data was collected from the project sites of Chawama, Chazanga and George compounds through interviewing the target population of household heads who are the perceived decision makers and income earners in household's whist secondary data was collected from faecal sludge and solid waste emptying and collection service providers in all the study areas. From Chawama, a total of 4,054 respondents were selected while Chazanga and George had total respondents of 4,133 and 1816 respectively based on probability proportionate to size. Systematic random sampling method was used to select the ten thousand and three (10,003) households that participated in the household survey. That is, the total number of households in the area (sampling frame) was used from the already existing list/map of households as presented on the peri-urban area maps. The households were divided by the total sample size to determine the sampling interval of four (4). Every fourth household was selected from the sampling frame, and a total 10,003 households were recruited. Each of the 50 research assistants was allocated 200 households to interview.

Testing of Pit-Latrine Emptying Equipment in Lusaka

In the period September to December 2017, GIZ through the CFS-Lusaka Project conducted field testing of three innovative pit emptying equipment to determine their suitability to be used to empty pit latrines in Lusaka. The exercise was aimed at establishing the best semi/ or fully mechanized equipment that can be adopted for the Lusaka context to improve safety and efficiency of the emptiers who currently use manual emptying methods that is through the use of elongated scoopers, picks and shovels. The three technologies consist of (i) the Gulper, (ii) the eVac MK3 and (iii) the Flexcravator and Flex-X. The Gulper technology is a manually operated while the eVac MK3 and Flexcravator are mechanized. The Gulper was provided by Sanitation Solutions Group (SSG) based in Kampala, Uganda, the eVac MK3 from the organization Partners in Development (PID) based in KwaZulu-Natal, South Africa, and the Flexcravator (and its derivative the Flex-X) is an improved version of the Excrevator from North Carolina State University (NCSU) in the United States of America.

All the technologies tested were accessed to determine their suitability and sustainability using the technology applicability framework (TAF) method developed under the WASHtech project and detailed in Olschewski & Casey [36]. The TAF indicator sheet and questionnaire was adapted to meet each technology specifications and the local context. Testing of various emptying equipment was to establish the best fitting technology that can address the issues of sanitation service delivery as well as deal with the current situation of solid waste in pit latrines. The technologies were tested with the objective of: assessing the equipment applicability in the general local context and in regard to emptiers needs; identifying potential challenges and necessary improvements for an adequate and sustainable possible uptake of the technology; and potentially addressing bottlenecks in Lusaka and to aid in comparing all the tested equipment and inform the most appropriate technology for Lusaka's emptying business climate; and if the technology is sustainable and scalable in the local context. In all the tests conducted, manual pit emptying tools were carried along so that the pits could be emptied if or when the equipment under test was challenged or completely failed to perform.

- The first desludging equipment invited and tested was the Gulper brought in by Sanitation Solutions Group (SSG) from Uganda. The Gulper equipment is a manual direct lift pump with the use of butterfly valves. The equipment is designed to empty supernatant sludge layers on the top of the pit whose depth depends on the length of the Gulper pipe which can also be extended depending on the design or the availability of adaptors. The standard gulper will reach 1-1.5m into the pit and the extendable Gulper will reach up to 2m into the pit. The Gulper was aimed to be tested on 12 sanitation facilities located in Chazanga and Kanyama Peri-urban areas of Lusaka. The facilities comprised: 7 pit latrines; 4 septic tanks and 1 cesspit (a one chambered containment facility receiving flush wastewater from user interfaces).
- The second sludge equipment tested was the Flexcrevator which is also termed as "Flex X". This equipment was a prototype of a project by the North Carolina State University (NC State) with funding from the Bill and Melinda Gates Foundation to prototype, test, refine and manufacture a pit emptying device. The Flex X comprised of two main components; a trash excluder mechanism which is designed to push away solid waste in pits from the sludge suction pipe during emptying thus leaving the solid waste or trash in pits; and vacuuming system for sucking out the sludge from the pits into a transport container. The equipment is powered by a motor either connected to grid power or a fossil fuel electric generator and was designed to only takeout the sludge from the pits and leave the trash in the pits. The prototype was tested on 8 sanitation facilities which had a wide range of sludge consistency and solid waste content in Chazanga and Kanyama peri-urban areas of Lusaka. The facilities comprised: 7 pit latrines and 1 septic tank.
- The third equipment tested was the eVAC_MK3 from the GIZ partners in Development from South Africa. The eVac is an innovative portable and compact equipment designed to empty pit latrines located in densely populated communities that are inaccessible by big trucks such as vacuum tankers. It uses a small vacuum pump to create a working vacuum of up to 0.8 bar in a 75 liters' vacuum tank. It comprises of two key components: the vacuum pump itself, which is powered by a 1.5 kW electric motor and mounted on a wheelbarrow-like chassis; and the vacuum tank. The eVac_MK3 was tested on 7 sanitation facilities in Chazanga and Kanyama peri-urban areas which had a wide range of sludge consistency and solid waste content. 6 pit latrines and 1 cesspit were scheduled to be emptied with the technology.

Key stakeholders from the sanitation sector including sludge emptiers, researchers, NGO's, implementers and the municipality were invited to take part the field testing and scoring of each technology as per TAF standards. Before the field testing, all were introduced to the TAF method/tool and trained on the content and usage of the adapted questionnaire. During the training session, each technology was briefly presented to the stakeholders. After the field testing (which lasted three days for each technology) the CSF project team aggregated and analysed the data from the field questionaire (filled-in by all participants in the field) for dissemination to all stakeholders. Lastly, a scoring workshop was held with all the stakeholders at the end of each technology field testing. The purpose of the scoring workshop was to stimulate discussions and debates regarding the performance of the technology and its potential for adaptability and scalability within the Lusaka FSM business market. The scoring was done using the TAF standard traffic lights system [36].

Quantification of Solid Waste from Emptied Containment Facilities:

Solid waste samples for quantification were obtained from sludge emptied from on-site sanitation facilities during the pit emptying activities. The sludge was emptied from households that had requested and paid the pit emptying teams from either Chazanga or Kanyama for their services. During the pit emptying exercises from household's containment facilities, information concerning household sanitation systems was also collected. More information on household solid waste management and FS emptying practices were obtained through questionnaires and field observations that took into account characteristics that affect operations and maintenance of FS facilities such as building materials used, age of the sanitation facility, size of toilet faecal hole, space inside toilet and access to toilet faecal hole. The separation of solid wastes was done by 2 methods. The first method involved the emptying of barrels in the receiving bay, rinsing the FS to flow into the treatment system and removing the solid waste that remains on the steel mesh. The number of barrels was recorded together with the amount of solid waste that was removed from the steel mesh. In cases when a barrel was filled with mostly solid waste, it was emptied directly on the ground and spread out to dry before the solid waste was measured. This solid waste still had a substantial amount of FS remaining. The weight of the solid waste was recorded in a note book with the number of total containers emptied from an individual pit. The weight of the solid waste from each containment facility was recorded against the volume of sludge emptied in order to project the potential solid waste content per cubic meter of contained sludge in sanitation facilities per area.

Collection of Information from FSTP's:

In order to know the faecal sludge market potential of serviced areas in Lusaka, semi structured interviews were conducted with faecal sludge service teams (pit emptiers) and treatment plant managers on the challenges encountered during pit emptying and sludge treatment. The teams interviewed were with the Kanyama pit emptying team, the Chazanga pit emptying team and the treatment plant managers from the respective teams. Sludge emptying records from the treatment plants were also collected and analyzed. Faecal sludge from latrines was found to contain inorganic solid waste. The effects of inorganic solid waste contained in the sludge in emptying were questioned in the process of understanding how the waste affects service provision quality. The interviews focused on pit emptying technologies, household waste management practices and solid waste management at the treatment plant.

RESULTS

The collected data from the study was analyzed quantitatively and the results were segmented according to three stages of the sanitation service chain – capture, storage and emptying, presenting all the findings of the methodologies for each stage and accompanying challenges presented by solid waste.

Sludge Capture & Storage and Solid Waste Management

A total of 16,500 toilets were surveyed in the mapping of sanitation facilities in Kanyama all of which were on-site sanitation facilities. From this, 12,000 toilets of the mapped facilities were found to be pit latrines of varying quality, including Ventilated Improved Pits (VIP), lined and unlined pits, and disused and/or buried pits and the remaining 4500 were pour flush facilities connected a treatment facility such as a septic tank (Water and Sanitation for the Urban Poor, 2018). The mapping signified that 73% of sanitation facilities in the PUAs are pit latrines. In the second sanitation mapping exercise for Chazanga, Chawama and George, Table 2 shows the types of toilets found in the project areas.

Table 2: On-Site sanitation facilities and their attributes in three study PUA's of Lusaka

Toilet Type	Chawama	Chazanga	George	Grand Total	%
Flushing toilets	391	2088	188	2667	12%
Ordinary pit latrines	4963	9545	3330	17838	77%
Pour flush toilets	451	1050	412	1913	8%
UDDT toilets	5	46	19	70	0%
VIP latrine	117	460	60	637	3%
Grand Total	5927	13189	4009	23125	100%
Lined	4597	7523	3102	15222	66%
Unlined	610	2909	532	4051	18%
Septic Tank and Soak away	720	2757	375	3852	17%
Grand Total	5927	13189	4009	23125	100%

The results showed that approximately 80% of surveyed household population in the PUA's rely on pit latrines of which the majority 77% are ordinary pits and 3% are VIP latrines. The remaining 20% use flush systems which are either full or pour flush connected to either a septic tank or a cesspit. For sub-structure facilities, 83% of the containment facilities are lined and out of which 66% are pit latrines and the other 17% are either septic tanks or soak ways. The remaining 18% were unlined earth pits. The low levels of water water-borne toilets in study areas were attributed to low water accessibility levels as water supply is either not there or reported to be erratic. Figure 1 shows graphical presentation of the predominant methods of faecal management by households in three of the four PUA's in which the study was done.

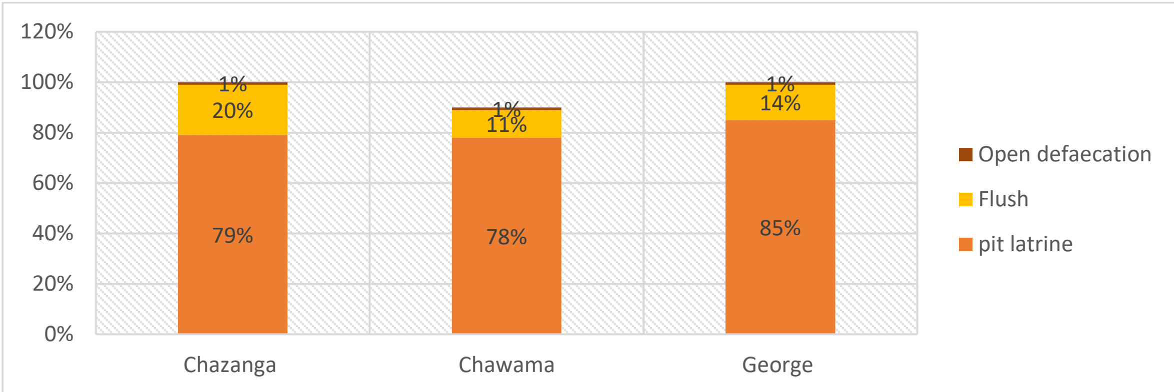

Figure 1: Commonly used sanitation methods in the three study areas of Lusaka

The containment facilities in the three PUA's were all found to contain sludge with 66% reported of having been found with more than half their containment volumes filled up. 5% of the facilities were very full and required empting services. Table 3 summarizes findings on the sludge containment proportions of On-site sanitation facilities in the study areas.

Table 3: Sludge containment levels in three study areas

Sludge Level	Chawama	Chazanga	George	Grand Total	%
Full	378	355	379	1112	5%
Almost Full	1018	1514	760	3292	14%
Half Full	3129	5876	1402	10407	45%
Almost Empty	1402	5444	1468	8314	36%
Grand total	5927	13189	4009	23125	100%

From all the 10,003 KAP respondents, various solid waste management practices in the PUA's came to light. The predominant practices include waste collection by Community Based Enterprises (CBE's), burying the waste on premises, burning the waste on premises or disposing the waste in sanitation containment facilities (e.g., pit latrines, septic tanks) and rain water drains. The waste management trend also depended on prevailing social and environmental conditions in each PUA and the availability of services. About 30% of all household produced solid waste could be thrown into pit latrines in areas lacking solid waste management services and a bare minimum of 1 % households solid waste in all surveyed areas reported that solid waste generated in the households end up in latrines pits no matter the level of service provision in the area. In addition, menstrual hygiene products and baby diapers are commonly thrown into sanitation systems due to the social and health aspects of the materials. Figure 2 shows the existing solid waste management practices in the target PUA's and the corresponding rate of practice.

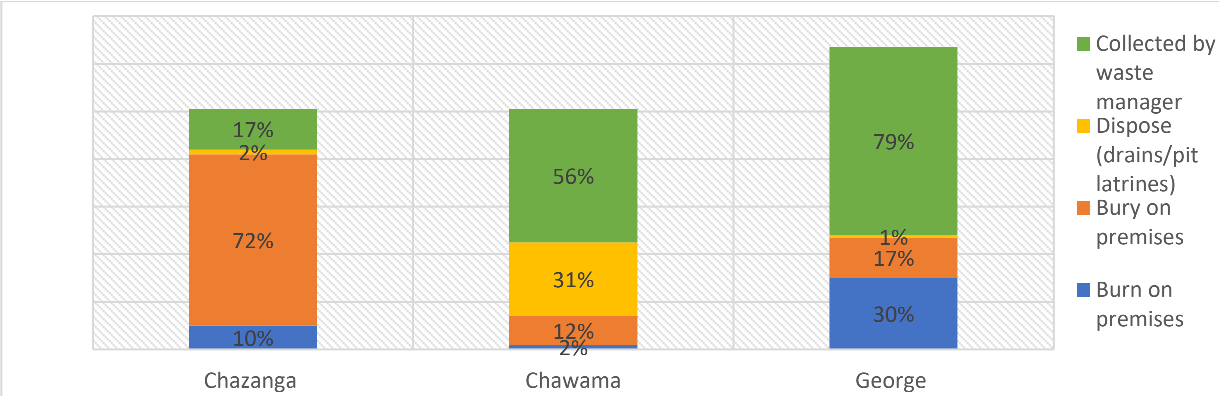

Figure 2: Solid waste management practices in the study areas

Sludge Emptying & Solid Waste Content

The respondents in the KAP provided four responses on how they empty sludge at their households. Figure 3 shows the sludge emptying method used in the three study areas.

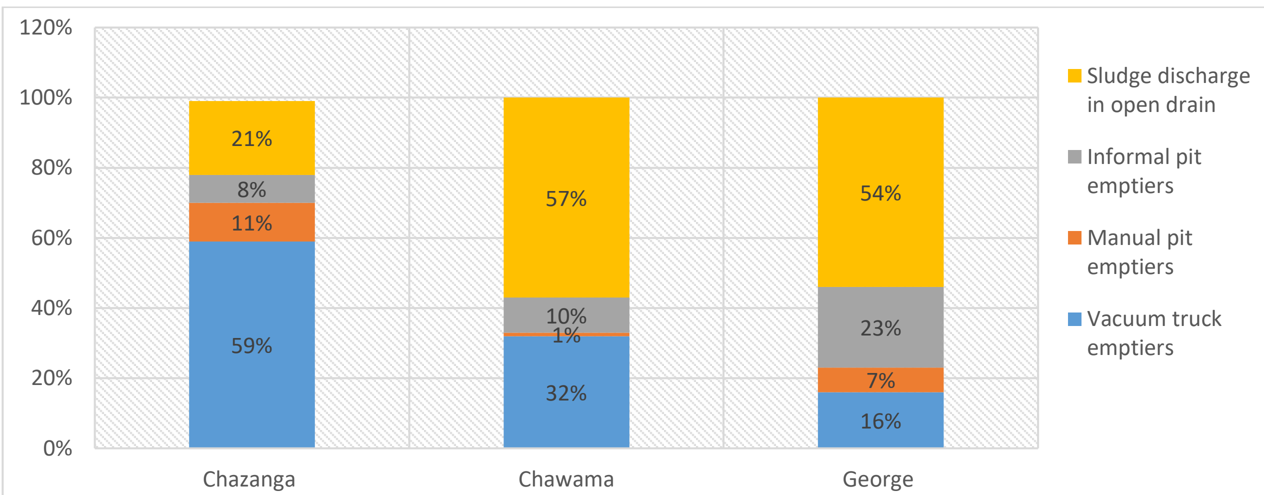

Figure 3: Sludge management approaches in PUA's of Lusaka

With the introduction of formalized pit emptying services by Lusaka Water and Sanitation Company through two water trusts in 2012, residents in the study PUAs started accessing hygienic pit emptying methods and they recognized the services of the water trust emptiers as formal. Table 4 gives records of services provided by the teams from 2013 to 2017.

From the inception of FSM services in Kanyama and Chazanga, records show that the pit emptiers were able to empty at least one containment per day. The average sludge volume from the emptied facility was 1.1m^3 per pit. Pit emptying teams from the water trusts in Chazanga and Kanyama however reported that emptying pit latrines was a challenge due to the presence of solid waste in the pits. Figure 4 gives a graphical representation of the sludge service levels by the Kanyama and Chazanga water trusts.

Table 4: Sludge emptying service levels by formalized service groups in PUA's of Lusaka

	Kanyama Water Trust FSTP										**Chazanga Water Trust FSTP**							
	2013		**2014**		**2015**		**2016**		**2017**		**2014**		**2015**		**2016**		**2017**	
	No of pits	**Vol (m3)**	**No of pits**	**vol (m3)**	**No of pits**	**vol (m3)**	**No of pits**	**Vol (m3)**	**No of pits**	**Vol (m3)**	**No of pits**	**Vol (m3)**	**No of pits**	**Vol (m3)**	**No of pits**	**vol (m3)**	**No of pits**	**vol (m3)**
JAN	_	_	32	36.72	40	56.16	28	38.4	_	_	_	_	7	7.68	12	30.72	18	24.48
FEB	12	15.36	45	10.32	14	25.44	_	_	57	82.32	_	_	7	14.64	21	40.32	15	20.88
MAR	36	47.52	31	32.64	25	29.76	_	_	21	29.04	_	_	11	21.36	29	15.12	22	31.68
APR	39	45.6	28	55.44	18	46.8	_	_	24	28.32	_	_	16	31.44	11	1.44	24	34.32
MAY	31	33.6	42	51.36	33	40.32	_	_	20	27.12	_	_	25	21.12	1	3.36	32	43.92
JUN	32	38.16	28	37.44	36	46.08	_	_	17	24.48	_	_	17	36.48	2	8.4	_	_
JUL	36	38.88	44	60.48	16	19.68	_	_	_	_	_	_	28	38.64	5	20.4	_	_
AUG	27	29.52	46	56.88	7	5.76	_	_	_	_	13	18.48	29	19.2	16	43.92	_	_
SEPT	45	53.52	58	80.16	33	41.76	34	52.56	_	_	6	6.48	16	44.64	27	51.36	_	_
OCT	47	52.08	56	77.52	35	43.44	62	88.08	_	_	14	13.2	33	42.48	31	54.24	_	_
NOV	56	64.32	57	75.36	29	38.16	54	67.2	_	_	15	15.84	32	46.08	37	39.6	_	_
DEC	30	37.68	43	53.04	25	32.88	_	_	_	_	12	12.96	37	15.84	29	24.72	_	_
Avg	**36**	**41**	**43**	**52**	**26**	**36**	**45**	**62**	**28**	**38**	**12**	**13**	**22**	**28**	**18**	**28**	**22**	**31**

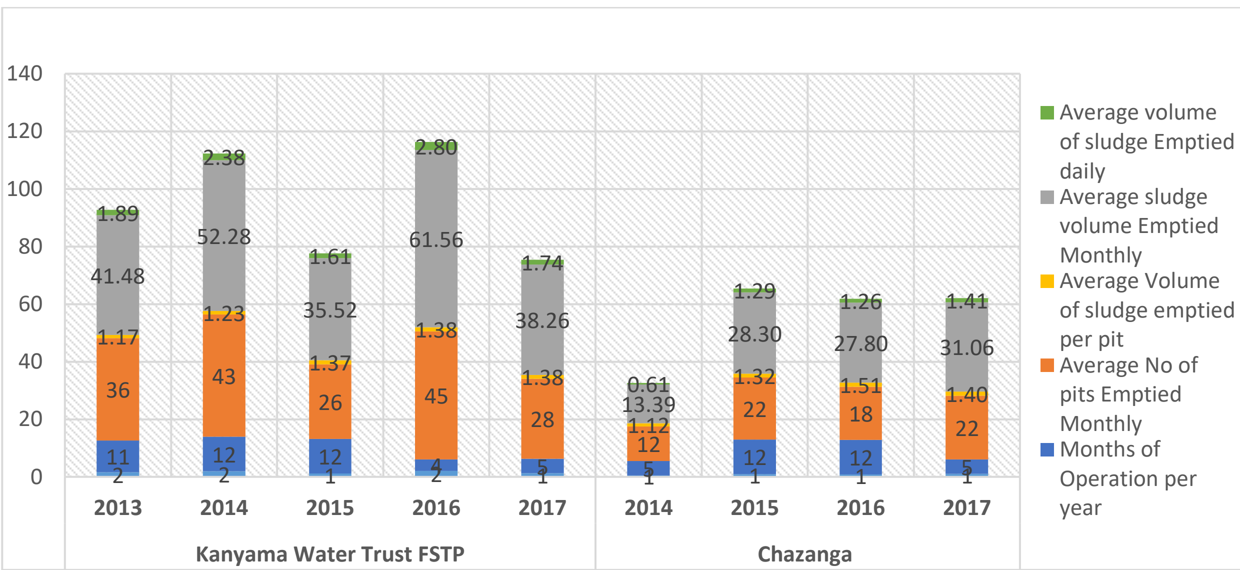

Figure 4: Sludge Service levels by the Water trusts in Lusaka by percentage by percentage

Emptying containment facilities for equal sludge volumes but containing solid waste was reported to take twice as much time compared to pits with no solid waste in them. This was attributed to the fact that pits with solid waste required additional tools and processes for the removal of the sludge and solid waste together. However, the required time for emptying varied from pit to pit depending on the quantity of solid waste contained in the sludge being emptied. To easy the removal of sludge containing solid waste from containment facilities, manual pit emptying teams add water into facilities during the pit emptying process. This is done in order to liquefy the content of pits and for ease of scooping the sludge emptied from the facilities. A 60 liters barrel of fresh water is added into the pit for every six barrels of 60 liters of sludge to be emptied translating to 16% of the total volume of FS to emptied to be fresh water added for easy emptying. Table 5 shows recordings of the measurements done during the solid waste quantification method.

Table 5: Solid waste quantification from OSS sanitation facilities in Kanyama

Sample 1: 2013		**Sample 2: 2013**		**Sample 3: 2013**		**Sample 4:2013**		**Sample 5: 2013**	
Pit Emptied/ Total Weight:		**Pit Emptied/ Total Weight:**		**Pit Emptied/ Total Weight:**		**Pit Emptied/Total Weight:**		**Pit Emptied/ Total Weight:**	
# Barrels Emptied	12	# Barrels Emptied	24	# Barrels Emptied	12	# Barrels Emptied	12	# Barrels Emptied	12
Barrel Volume (L)	60	Barrel Volume (L)	60	Barrel Volume (L)	60	Barrel Volume (L)	60	Barrel Volume (L)	60
Sludge Volume (m3)	0.72	Sludge Volume (m3)	1.44	Sludge Volume (m3)	0.72	Sludge Volume (m3)	0.72	Sludge Volume (m3)	0.72
Solid Waste:		**Solid Waste:**		**Solid Waste:**		**Solid Waste:**		**Solid Waste:**	
Weight 1	46.2	Weight 1	33	Weight 1	35	Weight 1	32	Weight 1	30.4
Weight 2	8.9	Weight 2	32.7	Weight 2	22.5	Weight 2	19	Weight 2	20.8
Weight 3	39	Weight 3	19.5	Weight 3	33			Weight 3	29.5
Weight 4	34	Weight 4	22.7	Weight 4	41			Weight 4	31.8
Weight 5	24	Weight 5	27.5					Weight 5	19.2
Weight 6	39.6	Weight 6	18.7					Weight 6	22.4
		Weight 7	26.5					Weight 7	23.8
		Weight 8	26.3					Weight 8	27.8
		Weight 9	41.5					Weight 9	21.2
TOTAL SW Weight	**191.7**	**TOTAL SW Weight**	**248.4**	**TOTAL SW Weight**	**131.5**	**TOTAL SW Weight**	**51**	**TOTAL SW Weight**	**226.9**
	266.3	**TOTAL SW Weight/m3 sludge**	**172.5**	**TOTAL SW Weight/m3 sludge**	**182.6**	**TOTAL SW Weight/m3 sludge**	**70.8**	**TOTAL SW Weight/m3 sludge**	**315.1**

The mass of solid waste measured per cubic meter of sludge from areas in the study with solid waste management services in 2017 ranged from 21.5 kg/m3 to 248 kg/m3. This measured solid waste content in the research represented a range from 10% to 17% with an average of 11%. Results from studies done in 2013 during the commencement of FSM services in Kanyama by the BORDA and WASAZA partnership ranged between 8% and 34% with an average solid waste percentage of 22% by weight. The results for the tests in two peri-urban areas are shown in figure 5

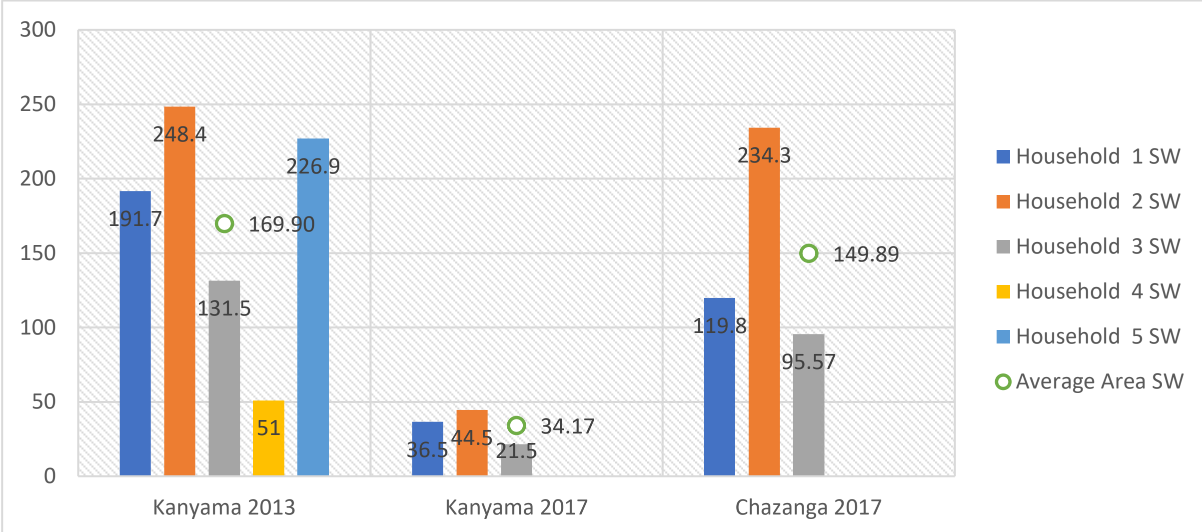

Figure 3: Solid waste containment in pits in two Peri-urban areas of Lusaka by year

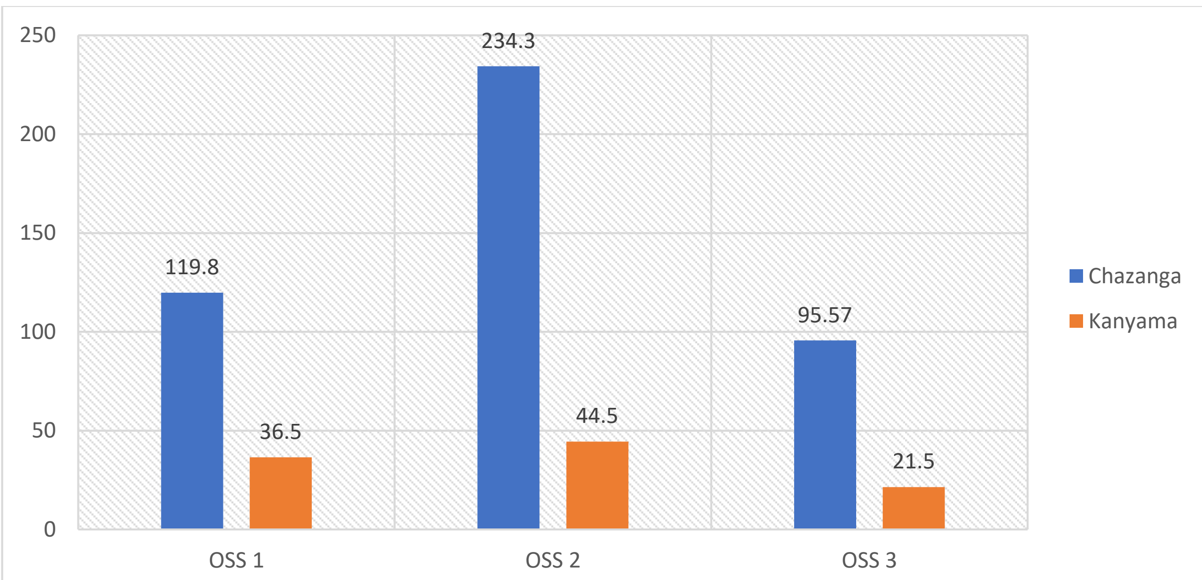

Figure 4: Mass of wet solid waste per cubic meter of faecal sludge from two peri-urban areas of Lusaka

Sludge Emptying Equipment Tests

On the use of technologies that have proven effective in other regions and countries, solid waste in containment facilities has shown to have adverse effects on their performance. The solid waste presented various challenges on pit emptying equipment. The testing and performance of each of the equipment tested is summarize below.

Of the 12 sanitation facilities targeted for emptying with the Gulper, only 5 facilities i.e. 2 pit latrines, 2 septic tanks and 1 cesspit were fully emptied using the Gulper. The gulper failed to empty sanitation facilities that had dry thick dry sludge with high contents of solid waste such as plastics and rags (common with most latrines in Lusaka). The solid waste led to frequent clogging of the Gulper's bottom butterfly valve. Even after the fishing process (i.e., the manual removal of solid waste from a containment by using a hook), there was still enough plastics and rags most containments (mostly pit latrines) thereby clogging the strainer of the gulper as well as getting into butterfly valves eventually blocking the Gulper. The other challenge faced by the Gulper was limited access to most containments due to structural limitations such as low roof height making it impossible to insert the Gulper in the squat hole and small squat holes which were less than the size of the Gulper's bottom cage.

Table 4: Gulper field performance

Pit Location	Type of Toilet	Comments
1. Chazanga	Dry pit latrine (Lined)	Pit not emptied with the Gulper as the sludge was thick and dry sludge hence could not be pumped); Emptied using modified garden tools
2. Chazanga	Dry pit latrine (Lined)	Pit not emptied using the Gulper as it contained lots of solid waste which could not be hooked (short hook); Emptied using modified garden tools
3. Chazanga	Cesspit - Pour flush	The pit was emptied using the Gulper; No structural limitations; No solid waste challenge
4. Chazanga	Dry Pit Latrine (UnLined)	Pit was not emptied using the Gulper; It had a challenging door position and gulper failed to access the pit; The pit was emptied using modified garden tools
5. Chazanga	Dry pit latrine (Lined)	The pit was emptied using both Gulper/ modified garden tools; Short roof height (roof was partially removed for gulper maneuver); The pit had lots of solid waste contained in it hence gulper frequently clogged
6. Chazanga	Septic Tank	Pit was not emptied using the Gulper; as it could not reach sludge fill level (depth > 2m length of Gulper)
7. Chazanga	Dry pit latrine (Lined)	Pit not emptied with the Gulper as the sludge was thick and dry sludge hence could not be pumped); Emptied using modified garden tools
8. Kanyama	Septic Tank	Not emptied using the Gulper; Gulper could not reach fill level (depth > 2m length of Gulper)
9. Kanyama	Wet pit latrine (used for bathing)	The pit was emptied using the Gulper; Toilet roof was however removed for gulper to access the pit; The toilet drop hole was enlarged for gulper to access Pit
10. Kanyama	Dry pit latrine	Emptied using the Gulper; shallow pit, emptier climbed on the roof during emptying as the Gulper was too long in relation to the pit depth
11. Kanyama	Septic Tank	The toilet was emptied using the Gulper; No structural limitations were encountered during emptying operations
12. Kanyama	Septic Tank	The toilet pit was emptied using the Gulper; No structural limitations were encountered during the emptying processes

Flexcrevator: This equipment was a prototype of a project by the North Carolina State University (NC State) with funding from the Bill and Melinda Gates Foundation to prototype, test, refine and manufacture a pit emptying device called the Flexcrevator. The prototype was tested on 8 sanitation facilities with a wide range of sludge consistency and solid waste content in Chazanga and Kanyama peri-urban areas of Lusaka. The facilities comprised: 7 pit latrines and 1 septic tank.

Table 5: Performance of the Flexcrevator in Lusaka

Pit # and Location	Pit Type	Sludge Type	Trash	Access method to the pit latrine	No. of 60L Barrels Emptied	Success Rate	Comments
1. Chazanga: Near Water Trust Office	Latrine	Dry	Lots	NA	NA	NA	Cable found already broken
Chazanga: Zone 13	Latrine	Dry	Lots	Top of the pit	6 out of 29 paid for	20.69%	Cable broke during emptyin
2. Chazanga: Olympia	Septic Tank	Wet	Scum only	Top of the pit	12 of 12 paid for	100%	Septic tank was emptied
3. Chazanga: Zone 1	Cesspool	Dry	Lots	Side hole	8 out of 32 paid for	25%	Auger slide on layer of trashand lots of auger head clogged
4. Kanyama: Near Water Trust Plant	Cesspool	Wet	NA	NA	NA	NA	Booked septic tank was found empty
5. Kanyama: Banda Masauko	Latrine	Dry	Lots	Top of the pit	NA	0%	Cable broke during emptying
6. Kanyama: Makeni	Latrine	Dry	Lots	Top of the pit with additional chipping	9 out of 32 paid	28%	Added 120 L of water to fluidize the sludge
7. Kanyama: Banda	Latrine	Dry	Lots	Side hole	3 out of 12 paid for	25%	Cable Broke during operation

Of the 8 facilities targeted to be emptied, the Flexcrevator only managed to successfully empty the septic tank. The equipment faced a lot of technical challenges. The Flexcrevator technology specifically encountered the common practice of solid waste disposal in pit latrines through its trash exclusion component. Though the Flexcrevator had an auger designed for trash exclusion during emptying, it was not successful in doing so as the mechanism was frequently clogged by plastics and rags.

Larger waste, such as bottles, brooms and shoes, were easily handled by the technology but a major issue comprised of plastics, rags and synthetic hair which caused the auger/trash exclusion system to clog frequently. Therefore, the solid waste exclusion is not sufficiently effective to handle the different types and sizes of solid waste that are prevalent in pits. Another possible cause of clogging of the auger was that the technology was rotating at an RPM less than 425 (design value) due to the difference in the power frequency (US: 60Hz and Zambia: 50Hz).

On average, six blockages were experienced per facility and the unclogging required the extraction of the auger end from the pit or the manual removal of the trash by hand/long stick/wires, leading to a direct contact of the pit emptiers to the FS and to spillages. Furthermore, the weight of the generator (separate of technology) was challenging and in some cases the truck could be parked close to the pit latrines and the machine remained on the truck to avoid its lifting. Due to the aspect that some drop holes are too small for the suction hose of the Flexcrevator in two households, two facilities had to be accessed through the side by breaking a hole into the pit structure and one facility was accessed by enlarging the drop hole. Therefore, holes that were less than 4 inches were rather difficult to access with this technology. Otherwise, the poor superstructure of the facilities tested caused no restrictions to the use of the technology as the pipe is flexible with a length of 2.5 m, and the machinery remains outside the facility. Also, the modular design and wheeled frame of the Flexcrevator allowed easy movement.

The eVac Mk3 proved capable to remove a huge range of sludge that was encountered in all the seven facilities. However, the speed and time to complete each emptying job varied greatly according to the sludge consistency and solid waste content in the pit. Generally, there were frequent stoppages to remove solid waste such as plastics and rags which blocked the end of the eVac's suction horse hose. The frequency of blockages increased once the more liquid top sludge had been removed leaving the dry thick bottom sludge which also had high solid waste concentration.

Table 6: Evac-MK3 performance on tested OSS in Lusaka

Pit Location	Type of Toilet	No. of 60L Barrels Emptied	Success Rate	Comments
1. Chazanga	Wet pit latrine (Lined)	17 out of 12 paid for	142%	Emptying was easy due to the wetness of the sludge and the relatively low trash content,.17 sixty liter barrels were filled fairly quickly.
2. Chazanga	Wet pit latrine (Lined)	24 out of 24 paid for	100%	Took 25 minutes to fill the first 20 drums. Thereafter the work slowed down. As the pit got empty the trash content increased and there were several stoppages to remove trash from the end of the hose. Took 30 minutes to do the last four drums.
3. Chazanga	Wet pit latrine (Lined)	4 out of 12 barrels paid for	33%	The sludge here was fairly thick and had a high trash content. The eVac performed well for the first four drums and the seal loosed after. Manual emptying was used to do the balance of the work.
4. Kanyama	Wet pit latrine (Lined)	7 out of 12 barrels paid for	58%	The eVac was able to suck thick sludge into 6 barrels without failure though the end of the hose had to be periodically removed to remove trash from the strainer. The seventh drum was filled without the stariner and then manual scooping was used for the balance. The trash content in the pit was high.
5. Kanyama	Pour flush toilet	12 out of 12 barrels paid for	100%	Acess through the hatch of the offset pit was easy. With the eVac the 12 barrels were filled in just 8 minutes.

	connected to cesspit			
6. Kanyama	Pit Latrine	2 out of 24 barrels paid for	8%	Sludge could not be removed as the pit was found full of sand/ash.
7. Kanyama	Pit Latrine	30 out of 32 barrels paid for	94%	The eVac was able to suck the sludge though the strainer had to be periodically removed periodically to remove trash. 30 barrels of sludge were emptied in an hour. The last two barrels were manually emptied due to too much trash. Out of the 32 barrels emptied approx. 7 were filled with trash. 3 barrels of water were added to the pit during the emptying process to fluidize the sludge for easy emptying.

The speed of sludge evacuation by the Evac varied greatly according to the sludge consistency and trash content. With the more liquid sludge encountered, the eVac's 40 litre vacuum tank was filling in just a few seconds and time was only lost due to the need to fill the eVac tank twice for every 60 litre sludge drum. At the fifth site, which was a pour flush pit with a fairly liquid sludge, 12 drums were filled in just 8 minutes. However, at other sites such as the second pit, once the more liquid sludge had been removed and evacuation reached the bottom of the pit where all the trash had concentrated, then there were frequent stoppages to remove trash which had blocked up the end of the hose.

DISCUSSION

The management of solid waste through containment facilities brings in the high requirements of operations and maintenance of OSS facilities at household level and trickles down through the whole sanitation service chain posing challenges in the provision of proper FSM services and risking public health in PUA's of Lusaka. The presence of solid waste in sludge containment facilities presents challenges in the emptying of the facilities. In the first instance, solid waste necessitates the side puncturing of sanitation facilities for emptying technologies to be able to access the sludge contained and for the equipment or emptying tools to be able to scoop the sludge. The puncturing of pits compromises the integrity of the structure. Each of the manual pit emptying teams in the city reported to experience the collapse of at least one OSS facility annually. from the results of the field performance of the three-pit latrine emptying technologies that were tested in 2017, it was clear that none of the technologies offered an advantage over the current method of manual emptying (i.e., the use of an elongated scooper) practiced in Lusaka when it comes to dealing with the problem of solid waste in pit latrines. The Gulper encountered several challenges when emptying pit latrines of different structural configurations. The technology could not access some pits due to structural limitations of these facilities to accommodate the height and dimensions of the technology, i.e., some pit holes were too narrow and needed enlargement and/or the pit latrine depth were too shallow or roofs too low which meant the length of the Gulper (pipe) could not fit unless the roof was either partially or fully removed. Some customers however would not give consent to having their pit latrine superstructure altered, i.e., the roof removed, or their structure modified in order to allow the

Gulper to access the pit contents. Despite these concerns, the users were positive on some attributed aspects to the use of the Gulper such as the technology is not complex and is easy to use, and is not inhibited by any cultural or religious taboo.

Faecal Sludge in PUAs containment facilities is managed through various interventions by different service providers ranging from household members themselves and informal service providers who empty sanitation facilities in the three (3) areas (Chazanga, Chawama and George) whose processes are unhygienic and poses a great threat to the environment and also by formal manual emptiers from water trusts or by vacuum truck operators. In most instances household members and informal pit emptiers dig pits near the pit latrines within the premises and bury the faecal sludge. In the case of Chawama, the Kanyama Water Trust team also provide services. Some residents in these areas with septic tanks hire vacuum tankers from private entrepreneurs who empty their facilities. Households in the area generally consider the emptying cost rates from vacuum tanker operators as relatively much higher than other service providers like manual emptiers.

The Flexcrevator addressed the issue of unsafe manual emptying practices through its flexible pipe and vacuum system, therefore making the handling of FS more hygienic, safe and faster (depending on sludge consistency). It also addressed the common issue of solid waste in pit latrines through its separation component. However, it was not able to handle all types of trash found pits. There were lots of cable (flexible) breakages that occurred during the testing exercise and can rendered the Flexcrevator-Flex-x unreliable during the tests. The technology however met some of the expectations of the pit emptiers in that it provided cleaner emptying practices. Pit emptiers showed interest in the Flexcrevator technology and the service it can provide, especially regarding its potential of solid waste separation, reduced risk of exposure to FS for the emptiers and ultimately providing a cleaner, safer service. The technology brings in an extra benefit for the need of improved solid waste management practices at household levels as can be influenced by the aspect that the solid waste remains in the pits after the emptying process. The technology silently but strongly emphasizes the need for an improved SWM and sensitization for proper solid waste disposal to improve. But its need for electric power from the households or the availability of a generator may lead to difficulties for pit emptiers to do their job and end up with its rejection by households in communities. In addition to this, it was assumed that households might not be able to afford the emptying fees which may well be higher than the current emptying fees owing to the fact that fees are expected to increase due to the added energy requirements, and the increased capital and maintenance costs that the technology could demand. Weaknesses of the technology that impact the satisfaction of the pit emptiers comprise of the break downs of the Flexcrevator due to the clogging of the auger as well as the weight of the technology, which is too heavy to lift and carry. In addition, the technology takes much longer to empty latrines when faced with solid waste. Necessary technical improvements are important to prevent dissatisfaction and rejection by the pit emptiers and communities/households. The results of the field testing gave the design team some perspectives and insights on how best the trach exclusion mechanism (the auger) can be designed to address trash clogs seen in the field. Although the Flexcrevator does meet expectations as it offers cleaner emptying of pit latrines through its flexible structure and solid waste exclusion component, a number of technical improvements are necessary to guarantee its satisfactory usage. The design needs to be adjusted to run at 450RPM and a have a power frequency of 50Hz to suit the Zambian scenario. After this another testing round is necessary to identify whether this change improves the solid waste exclusion system. The results of the field testing gave the design team some perspectives and insights on how best the trach exclusion mechanism (the auger) can be designed to address trash clogs seen in the field. The equipment found it difficult to avoid clogs with the trach exclusion mechanism design.

The eVac MK3 proved able to remove the range of sludge that was encountered over the four days of testing and the involved seven pits but it did not offer any advantages over manual scooping method when it came to sludge with a high trash content. Due to this shortfall of the technologies in meeting and solving the current challenges being faced by the emptiers with regards to solid waste in pits, the emptiers in Lusaka expressed preference and continued the use of modified garden tools. The current method of manually emptying pits with the scooper has proved more robust and suitable to empty pit latrines (the solid waste is simply scooped together with the sludge). The solid waste presence in sludge makes the pit latrine emptying job difficult no matter the technological approach as more time has to be spent at the household's facility separating the solid waste from the sludge during emptying. Interviews with households revealed that the existing OSS facilities in the PUAs are constructed with no standards and most even lack basic reinforcements to make them structurally stable. The lack of reinforcements and the puncturing of the facilities further endangers the pit emptiers from the collapse of system structures during emptying especially that they have to be punctured by the side or enlarge the shit hole for sludge to be accessed for emptying.

The effect of solid waste in sludge does not only end on emptying but also continues to affect the treatment of sludge at the treatment plant. Solid waste reaching the treatment plant is important to be understood as it impacts on the operations of the sludge reception and feeding facilities. On average, about 22% by weight of the brought in sludge at the FSTP in Kanyama during the inception of sludge management services was solid waste. However, the solid waste content in pits is highly variable from one PUA to the other: the minimum percentage of solid waste measured being about 8% and the maximum approximately around 34%. From the measurements solid waste measured from pits in Chazanga, the average wet weight of the sludge by percentage was 30%. The combined average solid waste content from latrine facilities from the two study sites and times was approximately 145 kilograms per cubic meter of sludge reaching the FSTP. This solid waste sludge negatively impacts the operations and maintenance of the treatment plant as it requires the need for extra Personnel for sludge handling during treatment – at each treatment plant, there is need of at least one personnel to be responsible for the washing out solid waste from the sludge during feeding of the treatment plant. The need for personnel to handle solid waste at the treatment plant entails the requirement for more resources to manage the treatment plant. The need to wash out the solid waste from the sludge further entails that there are longer operation times at the treatment plant. The emptiers reported that it takes about three times longer to handle and treat sludge containing than sludge that has no solid waste. This means that daily emptying services are also reciprocally affected as the emptying teams need to empty their sludge containing solid waste at the FSTP after each household before going back into the field for more emptying. The effect on the number of emptying services on the households means monthly income generations for the emptiers are drastically affected and this will continue if the households do not stop the throwing of solid waste in pits.

The sludge reaching the treatment plant needs to be separated out of the solid waste for it to be treated according to the required sludge product. At the two existing faecal sludge plants in Lusaka, solid waste is separated from the faecal waste in two receiving bays by means of vertical steel meshes placed between receiving bays at the inlets. This solid waste separation mechanism has been observed to work effectively, though small particles of solid waste find themselves in the treatment facilities. The trapped solid waste is then removed from the receiving bays using a garden fork and is immediately put into a barrel (same as used for pit emptying) before being taken to solid waste drying racks. At this time the solid waste still contains a substantial amount of faecal waste and is very watery, and the use of a barrel does not allow for drainage of liquids before being placed on the racks. The collected solid waste is spread out to dry on the racks for an average of about seven days. As the solid waste still contains a substantial amount of water and organic waste when it is dumped on site, it thus requires a long drying time and results in a substantial amount of solid waste accumulating on site, creating untidy conditions at the transfer station site. However, it has been observed that before the sludge is completely dried, it is put in plastic bags. This stops the solid waste from drying thoroughly and thus the bags are heavier than necessary. Particularly in the dry season, the material should be completely dried in the sun. In addition to making the material lighter and easier to handle, this also provides disinfection. Sometimes, barrels from containment facilities mainly containing solid waste are emptied directly on the grounds of the treatment facilities and spread out to dry. This solid waste still has a substantial amount of organic matter remaining.

The separated and measured wet weight of the solid waste at the treatment plants still contains faecal contaminated of organic matter as not all the organics could be washed out and treated. It thus requires a long drying time and this presents a daily accumulative solid waste at the site creating untidy conditions at the transfer station site. To create space at the drying bay area some solid waste is packages in bags before it completely dries and this this prevents the solid waste from drying thoroughly and thus the bags are heavier than necessary. Particularly in the dry season, the material should be completely dried in the sun to make the material lighter and easier to handle for disposal and this also provides disinfection.

And in the need to properly manage the dry solid waste at the treatment plant, FTSP managers highlighted that about 5% of pit emptying generated income is used in properly managing and disposing the solid waste at the municipal dumpsite. The resources are used to buy bags in which the dried solid waste is placed in wait for transportation to the dumpsite and in hiring a truck for the transportation of the packed solid waste to the dumpsite. On an average, a sack is required to package solid waste coming from a cubic meter of sludge and each bag costs the service about USD 0.08 and the transportation of the waste to the dumpsite costs about USD 55 for a truck load of about 40 bags thereby bringing the monthly total cost attributed to solid waste handling and dumping to approximately USD 58. However, the dumping of solid waste from sludge treatment plants at the municipal dumpsite brings is a public health challenge and concern as there are scavengers at the dumpsite who try to pick out items for sale to unsuspecting residents of Lusaka. These scavengers are exposed to faecal contaminated waste as they do not usually care to know the source of the waste. And in times the waste is disposed at locations where trucks from supermarkets also dispose their waste, high levels of contamination are brought onto the scavengers as they could pick and consume food stuffs right there and then. Some of the food stuffs might also find its way into the communities where it could be consumed and thereby igniting epidemics.

CONCLUSION

A cornerstone of sustainable development in developing countries is the establishing of affordable, effective and truly sustainable waste management practices. Solid waste is found in most pit latrines due to social behavior trends of dealing with solid waste in most communities and the lack of a functional system for the collection and management of municipal solid waste. Cultural myths especially when it comes to menstrual hygiene products and baby products also lead to the containment of solid waste in sanitation facilities. Myths lead to menstrual hygiene products and baby diapers finding themselves thrown into sanitation systems. The contained solid waste provides challenges for pit-emptiers in separating it from the faecal sludge during sludge emptying from containment facilities. The results from the studies reveal that high amounts of waste are prevalent in areas lacking solid waste management services provided by either community-based organizations or the municipality. The study show that high volumes of solid waste are emptied from pit latrines while flush system containment facilities mostly contain menstrual hygiene products due to their consideration of them being a taboo to be openly seen. Therefore, most households either throw them in toilets, burn them or bury them with the easiest option being to throw into sanitation facilities. The challenges brought about by improper solid waste management methods bargain those methods for pit emptying will remain mostly manual and haulage to treatment facilities will always be tedious and expensive. The lack of success by innovative pit emptying machines and the need for them to have high suction power and diluted sludge before emptying begs the need for households to stop the trend of waste management through pits otherwise proper sanitation services shall not be attained at household levels especially wherever the need for emptying is required. The presence of solid waste also means that there is a high risk of contamination of the operators both during emptying and at the treatment plant and also further risk the ignition of an epidemic in communities near municipal solid waste dump site. The FSM approach in the areas surveyed PUA's of Lusaka shows potential for a sustainable business opportunity however further analysis to develop an appropriate business model which also approaches and considers the proper management of solid waste at household. The model will require the incorporation of appropriate technologies for the containment facilities, collection, transportation and treatment of both faecal sludge and solid waste. Therefore, for sanitation especially in FSM interventions to have a successful outcome, accessible, affordable, and hygienic service provision in solid waste in PUA households has to attained. And for this to be successful aspects of solid waste management policies, strategies and plans have to be established and be embraced by all stakeholders.

RECOMMENDATION

Sanitation is one of the basic determinants of quality of life and human development index. It is a fundamental requirement to ensure safe health, environment and the overall wellbeing of society. Unless proper, functional sanitation facilities are in use and complemented with the right types of hygiene behaviors, communities will be vulnerable to recurrent incidences of water and sanitation-related diseases. From the above case study, it is recommended that awareness on solid waste management must be enhanced in all communities especially for them to stop the disposal of solid waste in on-site sanitation facilities as the solid waste can come back into the community and ignite a public health emergency. However, solid waste management and sanitation campaigns in communities must be run in parallel with waste collection service e delivery. Lusaka City Council (LCC) should also develop a sustainable waste management strategy to deal with consistent garbage collection and emptying of septic tanks and pit latrines especially in peri urban areas. Marketing of formal and proper onsite sanitation services should be done as matter of urgency. This will provide residents with an option to deal with pit latrines that are full. Therefore, for FSM interventions to have a successful outcome in PUA of Lusaka, aspects of solid waste Policy and Planning have to be established and Waste Management Strategies or Plans have to be embraced by all stakeholders. It must however be emphasized that multiple public health, safety and environmental co-benefits accrue from effective waste practices which concurrently reduce GHG emissions and improve the quality of life, promote public health, prevent water and soil contamination, conserve natural resources and provide renewable energy benefits [37] . In order to ensure sustainability and great benefit for the beneficiaries; it's important that the key players who have the responsibility for service provision have adequate capacity in terms of human capital and equipment. It is therefore recommended for LCC, the national Water and Sanitation Council (NWASCO) to work with the Zambia Bureau of Standards and the Lusaka Province Planning Authority (LPPA) and develop standards for lined and other improved latrines/containments that do not allow human waste/faecal sludge to be in contact with the environment before it's properly treated. In order to improve the knowledge and attitudes of the population on sanitation and hygiene matters, there should be extensive awareness campaigns. This should be done way before the rainy season in order to avert the annual cholera outbreaks; the campaigns should to be done in the familiar language so that most residents can get the intended message. Furthermore, there is need to conduct periodic knowledge, attitude and practices study to ascertain adoption of safe hygiene and sanitation practices by the residents. The Lusaka City Council (LCC) together with other partners such as the ministry of health should also intensify public health inspections to ensure residents and business owners are compliant with safe hygiene and sanitation practices.

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APPENDICES

Toilet Mapping Questionnaire

1. What category of premises is this toilet located?
   a. Residential plot
   b. School
   c. Clinic
   d. Market
   e. Church
   f. Police station
   g. Bus stop
   h. Industry
   i. Shopping complex
2. Who owns it? (name of owner) ____________________
3. Phone number of the owner ____________________
4. Address/ plot number where toilet facility is located? ____________________
5. How many households use this toilet? ____________________
6. What type of toilet is it?
   a. Flushing toilet
   b. VIP latrine
   c. Ordinary pit latrine
   d. Pour flush toilet
   e. UDDT
7. Does it have a concrete slab?
   a. Yes
   b. No
8. What type of interface/toilet seating does it have?
   a. Toilet bow
   b. Flat hole
   c. Squat pan
   d. Hole with raised sit
9. What type of containment?
   a. Septic tank/soakaway
   b. Lined pit
   c. Unlined pit
10. Containment depth ____________________
11. Containment width ____________________
12. Containment length ____________________
13. Has the toilet or septic tank ever filled?
    a. Yes
    b. No

    If yes:
    When was the last time it filled? ____________________
    What did you do when I filled? ____________________
14. For public toilets. is there a Ramp, and wide door or guard rails especially for public facilities?
    a. Yes
    b. No
15. What type of roof is on the toilet?

a. Asbestos
b. iron sheets
c. cardboard
d. wood
e. no roof

16. What type of walls does it have? ______________________________
17. What type of floors does it have? ______________________________
18. Is there a light bulb within the facility (for night access)?
    a. Yes
    b. No
19. What type of floor does it have? ______________________________
20. What is the level of sludge in the containment structure? _________________________
21. Is there an emptying interface?
    a. Yes
    b. No

    If yes:
    What type of emptying interface is there? ______________________________
22. What type of road leads to the toilet?
23. Is the road leading to the toilet accessible throughout the year?
    a. Yes
    b. No
24. What type of vehicle can be used for accessing the toilet for emptying?
    a. Motorbike
    b. Push-carts
    c. Pick-up
    d. Truck
    e. Tanker

KAP Questionnaire
Section A: Household Economic and Demographic Data
Name …………………………………………………………… Sex ……………………………..
Marital status ………………………………. Education level …………………………………..
Occupation …………………………………………………...... Age …………………..
Number of people in the household ………………………..
Age groups of household members …………………………………………….
Possessions ……………………………………………………………………………………………
Terms of resident status (i.e. home owner, resident landlord, absentee landlord and tenant) ……………………………..…………………………………………..

Section B: Household Water Source
Characteristics of water source:

1. What is the source of drinking water? …………………………………………………………..
2. What is the source of domestic water? ………………………………………………………..
3. How reliable are the sources of water? ……………………………………………………….
4. How much is paid for water access? …………………………………………………………..
5. How do you store your drinking water? ……………………………………………………….
6. How do you treat your drinking water? ………………………………………………………..
7. What alternative sources of water do you have? ………………………………………………

Section C: Toilet Facility
Characteristics of sanitation facility:

1. What type of sanitation facility is used? ……………………………………………………
2. When was the sanitation facility built? ………………………………………………………..
3. How much did it cost to build the sanitation facility? ………………………………………………...
4. Is the sanitation facility in use/ functional? ……………………………………………………...

5. How many people use the sanitation facility? ………………………………………………………..
6. Is the sanitation facility clean? ……………………………………………………………………….
7. Is the sanitation facility suitable to menstrual hygiene management? ………………………………..

Section D: Willingness to Pay

Data was elicited from participants through experimental components, randomly assigned in specific ways.

Section E Operation and Maintenance

1. What methods are used to empty the sanitation facility? ……………………………………………….
2. How often do you empty the sanitation facility? …………………………………………………
3. Is the sanitation facility accessible to emptying service provider? …………………………………….
   If no, what are the limitations to access the sanitation facility?
   ……………………………………………………………………………………..
4. What are the filling variations in different seasons?
   Cold season ……………………………………………………………..
   Dry season ………………………………………………………………
   Wet season ………………………………………………………………
5. How much does it cost for emptying service? ……………………………………………….

Section F: Solid Waste

1. What are the solid waste practices of disposal? ……………………………………………
2. What is the solid waste collection frequency? ……………………………………………
3. How much does it cost to collect solid waste? ……………………………………………
4. Who are the solid waste service providers? ……………………………………………………

Section G: Hand Washing

1. What material are used for handwashing? …………………………………………
2. When are hands washed? ……………………………………………….
3. Are there any hand washing facilities and stations around? ………………………………………….

Section H: Attitudes

1. What is your understanding of sanitation and hygiene? …………………………………………
2. Why do you think you need to maintain good hygiene? ……………………………………………
3. What are the ways to maintain good hygiene/be hygienic? ……………………………………………
4. In your opinion, when do you think are the critical times to wash your hands? …………………………
5. What are the ways to maintain good sanitation? ……………………………………………
6. How does a person get diarrhoea? ………………………………….
7. What are the 3 most important ways to prevent diarrhoea? ……………………………………

Faecal Sludge Quantification and Characterisation Questionaire: Households Survey Questionnaire

Section 1

User Approval ____

Section 2: Toilet Usage information

2.1 How many households/institutions use the toilet?

____

2.2 How many people use the toilet?

____

Section 3: Toilet facility information

3.1 What type of on-site treatment is it?

a) Lined pit latrine
b) Unlined pit-latrine
c) Septic tank

3.2 When was the facility implemented constructed?

____

3.3 What is the dimension of the implemented facility?
Length
Width
Depth
3.4 Is the pit accessible for emptying from the inside?
Yes
No
3.5 Is there any water connected to the containment facility treatment facility and from which system is the water from (e.g. shower, laundry, kitchen water, etc.)? Circle the applicable answer
Yes
No
If yes, please specify ______________________________
3.6 How many times has the pit been emptied? (0=none,1=once, 2= twice etc.) ________
3.7 When last was the pit emptied? ______________________
3.8 Who emptied it? ______________________________
3.9 What method of emptying was used? (vacuum truck, water trust pit emptier, neighbourhood emptier or household) __________________________
3.10 Where was the emptied solid waste taken?
3.11 Does the Solid waste enter the Faecal Sludge containment?
Yes
No
If yes, what types (e.g. hygiene products, food waste, other)?

3.12 Do you add bio-additives?
Yes
No
If yes, how often? __________________________
3.13 If Septic Tank, how many chambers? __________________

Section 4: Desludging

4.1. How many drums of faecal sludge have been emptied at the time of the last emptying?

____

4.2. Was water added and how much water was added?
Yes
No
4.3. How much solid waste was removed? ____________________
4.4. What is the volume of sand? (assessment done by technical team) ____________

Section 5: Site Condition

5.1. What is the ground condition of the emptying? Tick the applicable
Soil
Soft rock
Hard rock

Section 6: The Solid Waste Situation

6.1. Are there any existing solid waste management practices at the households?
Collection
Segregation
Disposal
6.2. What is the amount and type of solid waste generated (kg/day, kg/month, kg/year)?