

Methods and Means for Collection and Transport of Faecal Sludge

Georges Mikhael, David M. Robbins, James E. Ramsay and
Mbaye Mbéguéré

Learning Objectives

- Understand the social, procedural and technical aspects related to the collection and transport of faecal sludge from onsite sanitation technologies, and of its range of magnitude.
- Know which types of equipment can be applied for different types of onsite sanitation technologies.
- Be aware of the issues and the variables at play in the transport of faecal sludge to a treatment point or transfer station.
- Know what faecal sludge transfer stations are, how they are operated and factors that influence their location.
- Be aware of the health and safety issues regarding faecal sludge collection and transport.

4.1 INTRODUCTION

This chapter presents best practices in faecal sludge (FS) collection and transport that are applicable to a range of service providers, from sole proprietors with a bicycle driven cart, to large companies with multiple (sometimes hundreds) of transport vehicles operating in densely populated urban areas. Consequently, it presents a variety of techniques from the most basic manual sludge removal methods to those required for the most sophisticated vacuum truck operations. Often, due to the complexity of different types of onsite technologies, economic status and access, a variety of service providers can be found operating simultaneously in any given geographical region, and even within the same company.

People and companies that collect and transport FS from onsite sanitation technologies such as septic tanks and pit latrines perform a valuable service for residents, neighbourhoods and the cities where they are located (Figure 4.1). They provide a critical link in the service chain that makes access to sanitation a reality. Without collection and transport companies to remove FS, onsite systems will not function properly. This chapter is focused on the procedural and technical aspects related to the collection of FS from onsite technologies, transport to a location where treatment occurs, and the way in which service providers accomplish these tasks.

The objective of this chapter is to highlight aspects of an ideal, professional and safe sludge removal service. Effective service providers rely on trained personnel, functional equipment, and procedures for conducting the work safely and with minimal impact to the environment. Sanitation authorities should encourage measures such as worker training and certification, and licensing of collection vehicles. Activities should be adapted to suit the local context within which the services are implemented, while keeping these overall objectives in mind.

4.2 TYPICAL DUTIES AND RESPONSIBILITIES

Typical duties and responsibilities of FS collection and transport service providers include those that occur prior to the FS removal, the FS collection itself, and the subsequent transportation of the FS to the treatment facility. As will be explained in Chapter 12, service providers could be sole proprietors, different size companies, or a municipality.



Figure 4.1 Emptying operation of faecal sludge from a septic tank using vacuum equipment. Job safety would be improved by better protective equipment (photo: David M. Robbins).

When emptying the FS from onsite systems, a number of tasks are performed in accomplishing the job. Ideally, a typical job requires the service provider to:

- interact with customers prior to removing FS to arrange logistics and inform them of procedures;
- share the standardised fee or negotiate one, depending on the business model;
- locate onsite sanitation systems that are to have sludge removed;
- determine the accessibility of the system once it is located;
- open the system to facilitate the process;
- collect the FS;
- evaluate the condition of the system post-collection;
- close and secure the system once the FS removal has been completed;
- clean up after the process is completed; and
- perform the final inspection and report any issues with the system to the customers after the service is completed.

This section provides more in depth information on some of those activities that would ideally be performed prior to sludge removal tasks. The collection and transportation of FS are covered in more detail in later sections.

4.2.1 Interfacing with clients

The operator who comes to collect the FS is often the only person that a resident will interact with regarding their onsite system. As such, the operator has a responsibility not only to perform the tasks properly, but to be knowledgeable about the onsite system, and to be able to communicate why sludge removal is necessary and beneficial to the client and their community. The operator is also the only person who will be able to observe the onsite storage system both when it is full, and when it is empty. They should use this opportunity to assess how well it is functioning, identify repair needs and issues related to proper operation that might increase the life span of the system. As such, they can also troubleshoot and be a source of valuable information about FS management (FSM) in the community in which they work. This is also a good opportunity for service providers to work in conjunction with local governments to disseminate information, such as pamphlets on the proper care of septic tanks, or information on how unimproved latrines might be updated or improved to provide better service.

Case Study 4.1 : Customer Interaction in Marikina City, The Philippines

Marikina City, Philippines takes customer interaction a few steps further. Here the city, in conjunction with the water utility, has set up an organised sludge removal program that services neighborhood by neighborhood on a rotating 5 year cycle. They partner with the private sector service providers as follows:

- a few days before the service providers are in the neighborhood, they send out a truck with a loudspeaker to advise residents of the pending service;
 - the day before sludge removal takes place, the city workers visit the homes and pass out informational brochures;
 - they identify homes that require assistance in opening up their septic tanks and provide a list of people that can do this for a small fee; and
 - on the day of sludge removal, they are present to answer questions, direct traffic and troubleshoot.
- The result is 95% compliance with sludge removal requirements provided for in their local ordinance.



Figure 4.2 An example of an emptying operation in Dakar, Senegal where the system is located in an internal courtyard and gaining access requires cooperation with the residents (photo: Linda Strande).

Service providers work with residents at the household level to determine the location of the onsite system that requires emptying, to identify access ports and manholes (if they exist), to identify where to place their emptying equipment, and any other relevant issues. Frequently, onsite systems are located directly under the kitchen or bathroom, which makes entering the home with emptying equipment a necessity. Therefore cooperation and communication with residents at the household level is critical, and makes the emptying process more efficient. An example is shown in Figure 4.2, where an emptying operation is in process, with the service provider entering a courtyard to access the onsite system.

General rules that service providers should follow when interacting with household level residents include:

- being courteous and always obtaining explicit permission to perform the service;
- answering questions to the best of their ability and referring to the regulatory authority as needed;
- using caution when entering homes with hoses and other equipment, and protecting floors, walls and furniture from damage;
- communicating findings to the residents (preferably a written record of the service and any identified issues); and
- ensuring cleanliness during and after the service.

4.2.2 Locating the system to be emptied

Frequently, the location of the onsite sanitation system that needs to be emptied is not obvious. For example, septic tanks are typically buried and their location may not be known, and if latrines are grouped it is not always apparent for which one the service is being hired.

Methods to locate sanitation systems tanks include the following:

- asking the client the location of the tank;
- if not known, looking for obvious indicators such as manholes, tank lids or exposed concrete slabs, as shown in Figure 4.3;
- identifying sewer cleanouts outside or under the building. The direction of the cleanout might indicate the location of the tank;
- hammer a metal probe (e.g. one cm diameter metal rod) gently into the ground and determine by feel if rocks or tanks are encountered;
- looking for depressions in the yard around the house, which may signify the location of an underground tank;
- if the house is on piers, looking underneath to inspect the plumbing and determining if sewer lines or vent stacks are buried (scraping the earth around these pipes might indicate the location of the tank);
- if the house is constructed on top of a concrete slab, gently tapping with an iron bar on the floor to reveal hollow sounds.



Figure 4.3 Example of a septic tank access port designed for ready access, Vung Tau Province, Vietnam (photo: Linda Strande).

4.2.3 Determining accessibility

Determining the accessibility of septic tanks or pit latrines involves first determining if the site itself is accessible, and then assessing if each compartment of the system can be accessed to accommodate the FS emptying service. The following are typical factors that determine accessibility of a site:

Width of the road

- if using a truck, roads need to be wide enough to accommodate the truck or sludge emptying equipment.

Access to the site

- does neighboring property need to be accessed to reach the system;
- are there any weather related concerns regarding site access, such as stream crossings, or roads which are impassable during heavy rain event.

Location of the site

- if a truck or cart is being used, is the onsite system located close enough to the parking area to facilitate the emptying operation;
- is the client's location close enough to a FS treatment plant (FSTP) to accommodate transport.

The following questions can be used as a checklist to assist the service provider in determining if the system is accessible for emptying:

- can the system be opened to accommodate the sludge removal equipment (e.g. hose)?
- are there existing manholes over each compartment that can be opened?

- will the installation of new access ports be required? If so, is that a service that the residents have agreed to?
- will slabs, floors, or septic tank covers have to be rebuilt following emptying?
- will the pit collapse if emptied?

4.2.4 Tools of the trade

The sludge emptying process requires that the service provider has access to a number of tools and that the equipment is properly used and maintained. An example of inadequate maintenance is illustrated in Figure 4.4. The specific tools used by service providers vary based on the technology used and the availability on the local market.

Some tools common to all service providers include:

- shovels, pry bars and probes to locate tanks and manholes;
- screwdrivers and other hand tools to open manholes and access port lids;
- long handle shovels and buckets which may be necessary to remove solids that cannot otherwise be removed;
- hooks to remove non-biodegradable solids;
- hoses for FS pumping as well as for adding water to tanks if available; and
- safety equipment including:
 - wheel chocks to prevent the vehicle from moving when parked;
 - personal protective equipment such as hardhat, face protection, eye protection, boots and gloves;
 - disinfectants, barriers, sorbents and bags for cleaning up and collecting spilled material.

Employees of the collection and transport company should be responsible for maintaining tools and equipment in proper working order, and reporting to supervisors when repairs are required.



Figure 4.4 Hoses and fittings require frequent attention and repairs to keep them functioning properly. This picture illustrates inadequate maintenance, resulting in leaking of FS from the emptying hose (photo: David M. Robbins).

4.3 PROPERTIES OF FAECAL SLUDGE IN RELATION TO COLLECTION AND TRANSPORT

FS can be removed from septic tanks or latrines through the use of manual and mechanised techniques that may rely upon hand tools, vacuum trucks, pumping systems, or mechanical augers. The specific method utilised will be based on the type of onsite system, accessibility of the site, the type of equipment owned by the service provider, and the level of expertise.

Awareness of the properties of FS is necessary in order to understand the challenges faced in its collection and transport. These properties are primarily influenced by water content, sludge age, the presence of non-biodegradable material, and organic material. For example, within a pit latrine containment system, recently deposited FS found in the top portion typically has a higher water and organic content than that found in deeper layers, and consequently a lower density (Buckley, *et al.*, 2008). The top portion is therefore less viscous and relatively easy to collect. The absence of water and organic content in the deeper, older and more digested layers makes collection much more difficult, this condition is frequently referred to as ‘thick’. Depending on the collection method, ‘thick’ FS often needs to have water added to facilitate pumping. This suggests that the deposition period could be used as a strong indicator of the ease with which FS could be collected. FS characteristics are covered in more detail in Chapter 2.

4.4 MANUAL COLLECTION

Service providers using manual collection methods generally come from low-income communities living in informal settlements. They are often given offensive titles such as scavengers, *vyura* (Swahili for frogmen), *baye pelle* (pick & shovel men) or *kaka bailers* (excreta bailers). In some regions, they are members of ostracised groups, such as southern Asia’s *Dalit* (untouchables). However, regardless of how these social prejudices manifest themselves, the service providers often find themselves stigmatised within their own families and communities due to the nature of their work.

Manual sludge collection falls into two general categories, namely ‘cartridge containment’ and ‘direct lift’. Cartridge containment and direct lift methods can be practiced safely when operators perform their tasks with the proper equipment following appropriate procedures. For instance, descending into pits as currently practiced in several Sub-Saharan, and south and southeast Asian countries is not safe. Dumping of FS directly into the environment rather than discharging at a transfer or treatment site must also be avoided.

National and local governments, such as those in Ghana and Bangladesh, are starting to recognise the unsafe and unhygienic practises commonly used in manual sludge collection, and are prohibiting these activities. In addition, local government, can help promote hygienic FS collection by highlighting best practices, imposing restrictions on unsafe practices, and providing incentives such as training, capacity building, and licensing. Formalising the informal sector through training and licensing will drive the demand for improved services, will improve hygiene, and enable business development and job creation.

4.4.1 Cartridge containment devices

One example of a cartridge containment device is the “Uniloo” (Figure 4.6), an innovative technology designed for hygienic manual collection. This system consists of a modular, mobile, urine-diverting toilet, which has a replaceable and sealable cartridge waste tank (IDEO, 2012). Capable of holding approximately 20 litres of waste, the “Uniloo” isolates both users and collectors from direct contact

with FS. Collectors remove and seal a full cartridge and replace it with a pre-cleaned empty one on a regular basis, while the full cartridges are transported by low-cost transport and decanted at a transfer or treatment station using appropriate personal safety equipment and protection.

4.4.2 Direct lift

The direct lift method involves the collection of FS from latrines or tanks by using long handled buckets and long handled shovels. Filled buckets are hoisted to the ground surface, where they are emptied into tanks fitted onto carts which are then transported to transfer stations or treatment sites.

4.5 MANUALLY OPERATED MECHANICAL COLLECTION

Recent innovations in human powered mechanical devices are assisting service providers in servicing septic tanks and pit latrines more quickly, safely and efficiently. This section provides an overview of four (4) of the most common types of mechanical pumping equipment that has been developed and trialled; namely, the Sludge Gulper, the diaphragm pump, the Nibbler, and the Manual Pit Emptying Technology (MAPET).

4.5.1 Sludge Gulper

The Sludge Gulper, as shown in Figure 4.6, was developed in 2007 by the London School of Hygiene and Tropical Medicine (LSHTM). It is a low-cost manually driven positive displacement pump that operates along the same principles as that of direct-action water pumps.

The Gulper has a simple design, and can be built using locally available materials and fabrication techniques generally common in low-income countries. It consists of a PVC riser pipe containing two stainless steel ‘non-return’ butterfly valves. One valve, the ‘foot’ valve, is fixed in place at the bottom of the riser pipe and a second valve, the ‘plunger’ valve, is connected to a T-handle and puller rod assembly. As the handle is moved up and down, the two valves open and close in series and sludge is lifted up the riser pipe to exit the pump via a downward angled spout. A strainer is fitted to the bottom of the riser pipe to prevent non-biodegradable material from entering and blocking the pump.



Figure 4.5 The ‘Uniloo’s’ cartridge developed by Unilever, Water and Sanitation for the Urban Poor (WSUP) and IDEO in Ghana (photo: Nyani Quarmyne).

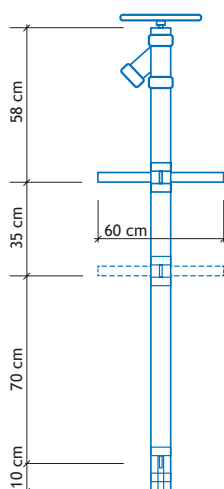


Figure 4.6 Schematic of the Sludge Gulper (Tilley *et al.*, 2014).

Since its initial development, the Gulper has undergone several modifications to make it more user friendly and better adapted to local conditions. Modifications that have been trialed include a lever-type handle to make pumping easier and a retractable riser to allow for the emptying of varying-depth containment systems. Other pumps have been developed that use similar principles, including the Poor Pump or the Manual Desludging Hand Pump (MDHP).

The Gulper performs well with less viscous sludge and is capable of pumping at a rate of approximately 30 L/min. The pumping head is fixed for each pump but is dependent on the configuration of the Gulper.

Depending on the design and materials used, the capital cost of the Gulper ranges from 40 – 1,400 USD (Boot, 2007; Godfrey, 2012; Still and Foxon, 2012).

Some challenges reported by developers and users of the pump include:

- difficulty setting up and operating the pump in toilets with a small superstructure (Godfrey, 2012);
- clogging of the pump by non-biodegradable material present in the sludge;
- cracking of the PVC riser pipe after long-term use; and
- splashing of wet sludge during operation (Godfrey, 2012).

Of the manually driven mechanical collection systems discussed in this section, the Gulper has reached the widest number of pit emptying service providers in Africa and Asia. However, independent uptake or production of the pump by service providers without the intervention of external organisations (e.g. funding, training, technical support) has not been reported.

4.5.2 Manually operated diaphragm pumps

Manually operated diaphragm pumps, as illustrated in Figure 4.7, are simple low-cost pumps capable of extracting low viscosity FS that contains little non-biodegradable materials. They typically consist of a rigid, disc shaped body clamped to a flexible rubber membrane called a diaphragm. An airtight seal

between the diaphragm and the disc forms a cavity. To operate the pump, the diaphragm is alternately pushed and pulled causing it to deform into concave and convex shapes in the same way a rubber plunger is used to unblock a toilet. A strainer and non-returning foot valve fitted to the end of the inlet pipe prevents non-biodegradable material from entering the pump and stops backflow of sludge during operation respectively.



Figure 4.7 Manual diaphragm pump operation in Bangladesh (photo: Georges Mikhael).

While they are light enough to be transported by one or two persons, in some cases the pumps are mounted on wheels for ease of transport. Depending on the model, the capital cost of a pump can vary between 300-850 USD.

The following challenges have been reported with this technology:

- clogging when pumping sludge containing non-biodegradable material;
- difficulties in keeping air-tight seals at fittings resulting in air entrainment and consequently low functionality;
- cracking of the rubber diaphragm (Muller and Rijnsburger, 1992); and
- difficulty in locally sourcing or manufacturing the pumps and spare parts.

4.5.3 Nibbler

A continuous, rotary action, displacement sludge pump called the Nibbler was developed by the LSHTM at around the same time as the Gulper. It is capable of collecting medium viscosity sludge using a continuous roller chain loop enclosed in a PVC pipe. The pipe can be inserted into the access hole of a containment structure or a pit latrine without the need to break any part of the structure.

The chain is driven by manually rotating a double crank and sprocket located at the top of the pipe. Semi-circular metal discs loosely and horizontally attached to the chain at regular intervals scoop out the waste from the bottom of the pit and displace it to the top. Once at the top of the pipe, sludge is scrapped off the discs and into a Y-shaped connector, which guides the sludge into the container being used for onward transport. A vertical plate spanning the length of the pipe divides the downward and upward travel directions of the chain and discs. Due to limited success during trials, development of the nibbler was suspended.

4.5.4 MAPET

In Tanzania in 1992, WASTE developed and trialled a human-powered vacuum system for the collection and short-distance transport of sludge called the Manual Pit Emptying Technology (MAPET). Of the technologies in this chapter, the MAPET is both the earliest and the most technically advanced manually driven mechanical collection system. It has two separate components, a pump and a 200 litre vacuum tank, each mounted on a dedicated pushcart.

From a technical point of view, trials have proven that the MAPET works well and is able to pump sludge from a depth of 3 metres at a rate of 10 to 40 L/min depending on the depth and viscosity of the sludge (Brikké and Bredo, 2003). Trials also concluded that WASTE succeeded in tackling most of the technical challenges that they initially set out to address. However, eight years after their introduction, only one of the eight MAPETs in Tanzania was found to be operational, and after thirteen years none were operational (BPD, 2005). Some of the reasons for their lack of long-term sustainability include:

- a breakdown in institutional support on which the service providers using MAPET were highly dependent;
- a reliance on the importation of a key spare part (a leather piston ring) which could not be sourced locally; and
- the inability of the MAPET service providers to recover maintenance and transport costs from emptying fees (WASTE Consultants, 1993).

4.5.5 Comparison of equipment

Table 4.1 provides a summary of the four manually operated mechanical equipment discussed in this section.

Table 4.1 Summary comparison table of manually operated mechanical equipment

Equipment type	Performance	Purchase/Operating cost (USD)	Challenges
Gulper	• Suitable for pumping low viscosity sludges • Average flow rates of 30 L/min • Maximum pumping head is dependent on design	• Capital Cost: 40 – 1,400 (depending on design)/ • Operating Cost: Unknown	• Difficulty in accessing toilets with a small superstructure • Clogging at high non-biodegradable material content • PVC riser pipe prone to cracking • Splashing of sludge between the spout of the pump and the receiving container
Manual diaphragm pump	• Suitable for pumping low viscosity sludges • Maximum flow rate of 100 L/min • Maximum pumping head of 3.5m – 4.5m	• 300 – 850 (depending on manufacturer and model) • Operating Cost: Unknown	• Clogging at high non-biodegradable content • Difficult to seal fittings at the pump inlet resulting in entrainment of air • Pumps and spare parts currently not locally available
Nibbler	• May be suitable for pumping higher viscosity sludges	• Capital Cost: Unknown • Operating Cost: Unknown	• May be unsuitable for dry sludge with high non-biodegradable material content
MAPET	• Maximum flow rates of between 10 and 40 L/min depending on the viscosity of the sludge and the pumping head • Maximum pumping head of 3.0m	• Capital Cost: 3,000 (1992) • Operating Cost: 175 per annum (maintenance costs only)(1992)	• Requires strong institutional support for MAPET service providers • A reliance on the importation of a key spare part • MAPET service providers unable to recover maintenance and transport costs from emptying fees

4.6 FULLY MECHANISED COLLECTION

Fully mechanised technologies are powered by electricity, fuel or pneumatic systems. They can be mounted on a frame or trolley for increased mobility, or mounted on vehicles for emptying and transporting large quantities of sludge over longer distances. This section introduces a range of fully mechanised technologies. It includes equipment that is widely available such as motorised diaphragm pumps, trash pumps and some types of vehicle-mounted vacuum equipment. It also details some less commonly used equipment that is either in early stages of development such as the motorised pit screw auger, or no longer being developed, such as the gobbler.

4.6.1 Motorised diaphragm pumps

Other than being powered by a motor, motorised diaphragm pumps operate using the same principles as the manual diaphragm pumps. Many different commercial brands and types exist covering multiple applications, one of which is the pumping of FS. Although they can be powered hydraulically, electrically or by compressed air, the most common type used for pumping FS is driven by a petrol or diesel engine. The pumps are typically mounted on a frame and moved by hand or using a trolley for increased mobility.

The performance of the petrol or diesel engine differs depending on the size and model. They are generally suited to pumping liquid sludge but can handle some solid particles (MSF, 2010). A typical 3-inch pump can pump solids ranging in size from 40 to 60 mm, with a maximum flow rate of 300 to 330 L/min, and maximum pumping head of 15 metres.

Motorised diaphragm pumps were used to empty VIP latrines in South Africa but frequently blocked due to the presence of large pieces of non-biodegradable material in the sludge (O’Riordan, 2009). A lack of spare parts for some components of the engine is also a constraint in some low-income countries.

The approximate purchase price of a 3-inch motorised diaphragm pump is 2,000 USD.

4.6.2 Trash pump

Trash pumps work in a similar way to centrifugal impeller water pumps, with some different features. The impeller of a trash pump typically has fewer solid blades, sometimes with cutting edges that can break up the material being pumped. The impellers’ housing is usually simple and easy to remove allowing for rapid unblocking if and when required (MSF, 2010).

Trash pumps are suitable for pumping sludge with high liquid content. Similar to motorised diaphragm pumps, the performance of the pumps differs depending on the size and model. The 3-inch pumps can typically handle solid particles in the range of 20 to 30 mm, have maximum flow rates of approximately 1,200 L/min, and maximum pumping heads of 25 to 30 metres. The approximate purchase price of a 3-inch trash pump is 1,800 USD.

4.6.3 Motorised pit screw auger

Pit screw augers (SAs) are based on the Archimedean screw design. Trials were carried out using manually operated AS, however they were found to operate too slowly to be effective (Still and O’Riordan, 2012). Motorised SAs are currently under development with prototypes mimicking certain aspects of commercial motorised soil augers. They consist of an auger placed inside a plastic riser pipe and protruding by approximately 5 to 15 cm from the bottom end of the pipe. An electric motor is mounted on top of the riser pipe where it connects to the auger (Figure 4.8).



Figure 4.8 Mechanised pit screw auger in South Africa (photo: David M. Robbins).

To operate, the riser pipe is placed in the FS and as the auger turns, FS is picked up by cutting blades at the bottom of the auger and lifted up the riser pipe along the auger flights. A downward angled spout at the top of the riser pipe allows material to be discharged into a collection container. Weighing between 20 and 40 kg, motorised SASs can be operated by one person. Flow rates are estimated to vary between 40 to 50 L/min and it may be suitable for pumping high viscosity FS and semi-solids. They can handle a small amount of non-biodegradable waste (de los Reyes, 2012), with more recent prototypes being fitted with a reverse gear to facilitate dislodging of waste. It is reported that one of the prototypes costs in the region of 700 USD to build, however no data is currently available on operating costs.

Some of the challenges faced by the motorised PSAs include (Still and O’Riordan, 2012; Still and Foxon, 2012):

- complicated emptying process due to the fixed length and rigidity of the auger and riser pipe;
- unsuitability for use with dry sludge and large amounts of non-biodegradable waste;
- difficulties with cleaning after use; and
- difficulties manoeuvring due to weight and size.

4.6.4 Gobbler

The Gobbler was prototyped by the South African Water Research Commission (WRC) in 2009 as a more robust and efficient version of the Nibbler. Using the same operating principles as the Nibbler, the Gobbler is powered using an electric motor. The motor turns a double chain drive that rotates a heavier gauge chain than that of the Nibbler. The metallic disks used to pull FS out of the pits in the Nibbler have been replaced by metal scoops, and a scraper is installed at the discharge point to remove the FS off the scoops (Still and O’Riordan, 2012).

During testing, sludge blocking the drive chains of the Gobbler was found to be a significant problem (Still and O’Riordan, 2012; Still and Foxon, 2012). Other issues encountered in the construction and operation include (Still and O’Riordan, 2012):

- a complex fabrication process requiring a high number of parts;
- difficulty moving and setting up the pump due to its heavy weight; and
- difficulty emptying containment structures of different depths as the length was not adjustable.

The estimated cost of the prototype Gobbler was approximately 1,200 USD. As with the Nibbler, and due to the significant challenges experienced, no further investments have been made in the development of the Gobbler (Still and Foxon, 2012).

4.6.5 Vehicle-mounted vacuum equipment

Pumping systems that utilise a vacuum have been shown to be effective at removing FS from onsite water-retaining systems. Vacuum pumps may be mounted on heavy duty trucks or trailers, on lighter duty carts or even on human powered carts when smaller volumes are being collected, or for use in dense urban settings not accessible by larger trucks. Vacuum pumps often utilise the truck’s transmission to power the system, although independently powered, dedicated motors can also be used. Vacuum trucks are available in a wide variety of sizes and models to accommodate different needs, with the most commonly used having capacities ranging from 200 litres to 16,000 litres. Different types of vacuum systems are described in the following section.

Conventional vacuum trucks

Vacuum pumps are sized based on lift elevation, pumping distance, volume of sludge to be removed, and volume of the tank. When designing collection and transport systems, local manufacturers should be consulted in order to determine what equipment is available. Product specifications must be checked to verify that the proposed truck is adequate for the need.

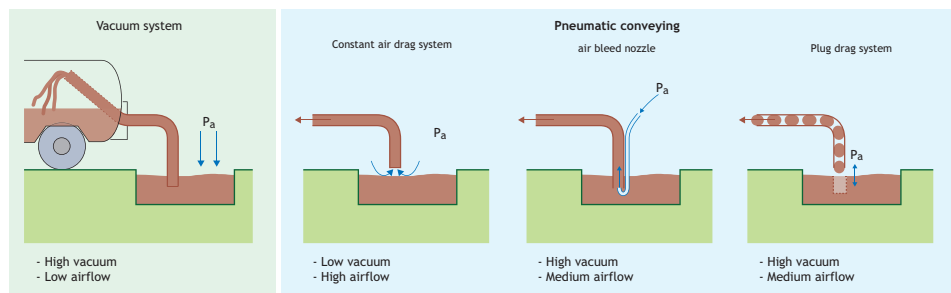


Figure 4.9 Four types of vacuum sludge removal techniques (adapted from Böesch and Schertenleib, 1985).

The typical volume of trucks used for the collection of FS ranges from 10,000 litres to 55,000 litres. Various factors influence the selection of a vacuum truck by a service provider, including:

- typical volume of the tanks or vaults that will be serviced;
- road widths and weight constraints;
- distance to the treatment plant;
- availability;
- budget; and
- skill level of the operators.

Conventional vacuum tankers are typically fitted with either a relatively low cost, low-volume sliding vane pump or a more expensive liquid ring pump. The former is more appropriate for low-capacity vacuum tankers where high vacuum and low airflow sludge removal techniques are used. Vacuum conveyance techniques work best for removing low-viscosity sludge such as that found in septic tanks (Böesch and Schertenleib, 1985).

Liquid ring pumps are more appropriate for high-capacity vessels and pneumatic conveying techniques. Three such techniques namely, constant air drag, air bleed, and plug drag, are briefly described in Figure 4.9. They are most suitable for emptying higher viscosity sludge typically found at the bottom of a septic tank or in a pit latrine.

Some conventional vacuum tankers are also fitted with dewatering capabilities in order to reduce the volume of the sludge transported and increase efficiency. Wastewater disposal points (typically a sewerage network) then become necessary to dispose of the untreated liquid effluent. The downfall of this more complex system is the expert maintenance needs, in terms of human capacity and spare parts.

BREVAC

In 1983, the International Reference Centre for Waste Disposal (IRCWD) undertook a series of field tests in Botswana using multiple conventional and specialist vacuum tankers as well as mechanical collection equipment. The BREVAC, developed by Building Research Establishment (BRE), was one of the specialist vacuum tankers being tested (Figure 4.10).

The equipment was designed to haul a double-compartmental vessel; the first being a 4.3 m³ compartment for sludge, and the second a 1 m³ compartment for service liquid (i.e. water) (Böesch and Schertenleib, 1985). It was fitted with a high performance liquid ring vacuum pump with a 0.8 bar suction capacity and 26 m³/minute air flow rate. The tanker was also fitted with a hydraulic tipping cylinder to incline the vessel and facilitate cleaning after it had been emptied.

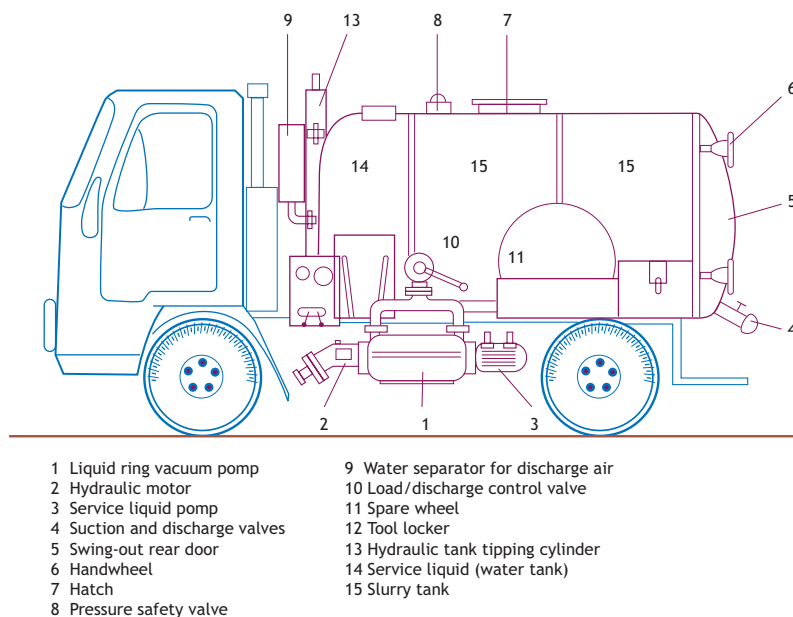


Figure 4.10 Schematic diagram of BREVAC (adapted from Böesch and Schertenleib, 1985).

During testing, the BREVAC proved to be capable of emptying high viscosity FS from pit latrines and manoeuvring in tight spaces and difficult terrain (Böesch and Schertenleib, 1985). Its ability to hydraulically break up sludge masses with pressurised water streams prevented the need for someone to get inside the septic tank or pit during cleaning. Some design features required reconfiguration (e.g. addition of a floating ball gauge to determine sludge level), and non-biodegradable materials caused clogging of the hoses. However, overall the technology was deemed to be technically sound and fit for purpose.

Due to the highly technical design and specialist parts necessary to operate it, and the high cost associated with such issues, the BREVAC failed to sustain demand and presence in the target market.



Figure 4.11 The Mark III (left) and Mark IV (right) models of the BREVAC collection and transport device (photo: Peter Edwards).

Vacutug

In 1995, lessons learned from the development of the BREVAC and MAPET by IRCWD were taken into account in the development of the UN-HABITAT Vacutug. The first version, Mark I, was developed in Ireland by Manus Coffey Associates (MCA), and trialled in Kenya by the Kenya Water and Health Organisation (KWAHO). Since then, a further four versions have been developed in Bangladesh, and several units of each sold. Examples are shown in Figure 4.11 and in Table 4.2.

Table 4.2 Different Vacutug versions and corresponding general properties

Version	Capacity (litres)	Relative Width	Travel Distance	Mounting & Propulsion	Cost (USD) (excluding shipping)
Mark I & II	500	Very Narrow	Short-Haul	Mounted on self-propelled chassis	10,000
Mark III	1,900	Average	Long-Haul	Mounted on trailer chassis and propelled by tractor or pick-up	20,000
Mark IV	700	Narrow	Medium-Haul	Mounted on chassis of motorised tricycle	15,000
Mark V	1,000	Narrow	Medium-Haul	Mounted on chassis of motorised tricycle	15,000

4.6.6 Delivering vehicle-mounted vacuum services

Vacuum units for sludge removal are complex mechanical systems that must be operated correctly, not only to accomplish sludge removal, but also to protect the equipment and health of the service providers.

The following steps are recommended for the operation of vacuum trucks:

- 1 Park the truck as close to the system as possible. The maximum distance is determined by the length of hose and elevation rise from the bottom of the pit or septic tank to the vacuum truck tank inlet. This should typically be no more than 25 meters in linear distance and 4 meters in elevation gain. Further distances or elevation differences may require intermediate pumps.
- 2 Inform the occupant of the pending service and note any concerns or issues.
- 3 Inspect the site for possible hazards, such as clearing the area of people, or identifying high groundwater that could cause a tank to 'float' if emptied.
- 4 Secure the truck using wheel chocks.
- 5 Lay out and connect the hoses from the truck to the tank or pit to be emptied.
- 6 Open the tank or pit by removing the access ports or covers over the storage system.
- 7 Engage the vacuum equipment by using a power take-off from the truck's transmission.
- 8 Increase the vacuum to the proper level with the valve closed by watching the vacuum gauge, then lowering the end of the hose into the storage system, and open the valve sufficiently such that the FS is drawn out of the tank or pit. Closing the valve periodically re-builds the vacuum to enable the removal of further FS.
- 9 Continue this process until the job is complete.
- 10 Break up FS that has agglomerated into a solid mass, either by making use of a long handle shovel and adding water when necessary to reduce the viscosity of the FS; or by reversing the direction of the flow and forcing the contents of the vacuum truck tank back through the hose and into the sanitation system in order to use the high pressure stream to break up the sludge. The direction of

- the flow is then returned to normal and the contents removed. It is essential to ensure that the hose is in sound condition, and that the hose connections are locked into place prior to using this method;
- 11 Operators should remove between 90% and 95% of the contents. It is recommended that this is verified by management through periodic spot checks.
 - 12 Identify any abnormal conditions, such as high concentration of non-biodegradable materials, oils and grease. The colour and odour of the FS can provide clues as to how the occupants are using the system, and if excessive chemicals are being discharged down the drain.
 - 13 Inspect the system once empty. In the case of a septic tank, the following checks should be carried out by the operator:
 - a. Listen for water running back from the discharge pipe, which could indicate plugged leach lines (if present);
 - b. Check to make sure that inlet and outlet tees are properly in place. Frequently, these structures break off and can sometimes be found at the bottom of the tank;
 - c. Inspect the tank for cracks or damage;
 - d. Verify that the tank is properly vented;
 - e. Ensure that the tank lids are properly attached when the pumping is complete and that they are properly secured;
 - f. Prepare a written report indicating:
 - how much waste was removed;
 - the condition of the tank or pit;
 - any recommendations for repairs or maintenance;
 - any recommendations for proper use of the system.
 - 14 Secure the tank lid and pack away the hoses;
 - 15 Clean up any spillage using proper sorbent materials;
 - 16 Inform the client that the work is complete, and give them the final report. In some instances, payment is received immediately for the service however, payment is often made directly to the service provider through some type of billing system. During this final interview, the operator informs the client of the findings and any recommendations;
 - 17 Remove the wheel chocks and drive the truck to the next site or to the nearest approved disposal site.



Figure 4.12 Example of correct method where the hose is easy and quick to assemble (photo: Linda Strande).



Figure 4.13 Example of an improperly maintained hose held together with plastic bags and twine (photo: David M. Robbins).

4.6.7 Summary of fully mechanised systems

Table 4.3 summarises the main aspects of the mechanised mechanical sludge emptying equipment discussed in this section, highlighting the performance, cost and concerns.

Table 4.3 Summary table for mechanised mechanical sludge emptying equipment

Equipment Type	Performance	Cost (USD)		Challenges
		Capital	Operating	
Motorised diaphragm pump	• can handle liquid sludge and solid particles 40 to 60 mm in size • maximum flow rate of 300 to 330 L/min • maximum pumping head of 15 m (can easily empty from variable depths)	2,000	Unknown	• blocking due to non-biodegradable waste in the sludge • spare parts not available locally
Trash pump	• can handle very liquid sludge and solid particles 20 to 30 mm in size • maximum flow rate of approximately 1,200 L/min. Maximum pumping head of 25 to 30 m (can easily empty from variable depths)	500 – 2,000	Unknown	• difficult to find spare parts • requires containment system • potential for clogging
Pit screw auger	• can handle liquid sludge and a small amount of non-biodegradable waste • flow rates of over 50 L/min. pumping head of at least 3 m (difficulty emptying from variable depths)	700	Unknown	• the fixed length of the auger and riser pipe • unsuitable for use with dry sludge and large quantities of non-biodegradable waste • difficult to clean after use • difficult to manoeuvre due to weight and size
Gobbler	• blocks easily due to sludge build up in the working parts • pumping head of at least 3 m • difficulty emptying from variable depths	1,200	Unknown	• complex fabrication process and a high number of parts • weight of the pump • length not adjustable
Vacutug	• can handle low-viscosity sludge well and some non-biodegradable waste • ideal for areas with limited access. • pumping head varies depending on model used	10,000 – 20,000	25 USD/load ¹	• can be slow to transport • difficulty emptying high-viscosity sludge • small volume (500 to 1,900 litres) • not financially viable for long-haul transport
Conventional vacuum tanker	• can easily handle low-viscosity sludge well and some non-biodegradable waste • Ideal for transporting large quantities of sludge over long distances • Pumping head varies depending on pump model used	10,000 – 100,000 ²	Highly Variable	• difficulty accessing high-density areas • difficult to maintain in low-income contexts due to specialised parts • prohibitively expensive for some service providers

¹ Assuming two loads emptied per day from an average distance of 10 kilometres from the disposal point and an average travel speed of 10 km/h (Mikhael and Parkinson, 2011)

² The price range of conventional vacuum tankers varies significantly depending on whether the vehicle is brand new or used, capacity, extra capabilities (e.g. jetting), and shipping costs.

4.7 TRANSPORT OF FAECAL SLUDGE

Most of the manually operated small-scale equipment described in Section 4.5 and some of the mechanised equipment described previously in Section 4.6 are not capable of transporting sludge. Low-cost transport equipment, standardised or customised, is therefore often used for the transport of sludge to the transfer station or treatment facility.

This equipment can be categorised into two main forms: that which is manually propelled by human or animal power, and that which is motor-propelled using a fuel-powered engine. This section describes the different types of manual and motorised equipment currently in use and presents their advantages and disadvantages.

The aspects that need to be considered for the transportation of FS include:

- the type of vehicle to be used including its road worthiness, maintenance, licenses and permits, and where it is kept when it is not in service;
- the type of sludge removal equipment, including hoses, pumps, augers, and other tools of the trade;
- the spill management equipment to be used including shovels, disinfectants, sorbents, and collection bags;
- the skills of the operator including the training and certifications that might be required to perform the work;
- procedures that need to be followed including rules of the road and activities at the treatment plant; and
- other aspects such as the use of transfer stations, worker health and safety, and emerging technologies.

4.7.1 Manual transport

Today, both standard carts used for general transport of materials, as well as customised carts designed specifically for transport of FS, can be found in many low-income countries, an example of which is shown in Figure 4.14. Although designs vary widely, standardised carts typically consist of a load-bed mounted on a single axle with one or more wheels. Containers of sludge with capacities of up to 200 litres can be carried on or in a manually pulled or pushed cart (Still and Foxon, 2012, Strauss and Montonegiero, 2002; Barreiro, *et al.*, 2003; Chowdhry and Koné, 2012). The carts are designed to be manoeuvrable in tight spaces and have an effective range of up to 3 km.

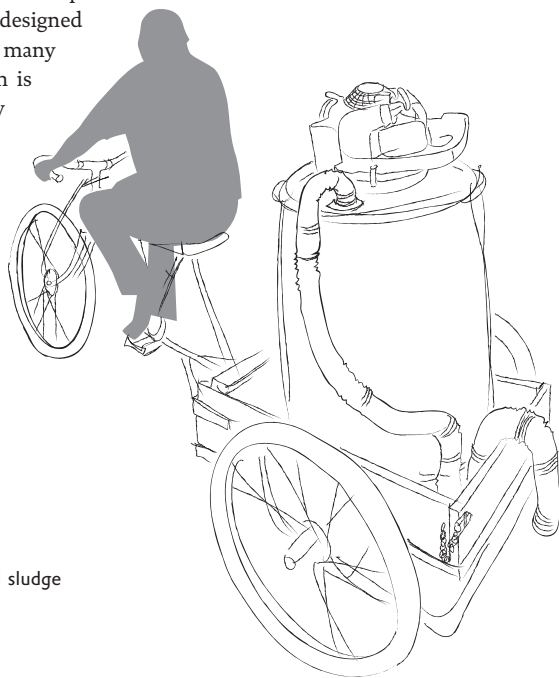


Figure 4.14 Schematic of human powered faecal sludge management transport technology (figure: Research Triangle Institute).



Figure 4.15 Sludge collection and transport vehicle navigating roads in the busy city of Manila, Philippines (photo: David M. Robbins).

Since manual low-cost transport equipment generally have a small load capacity, limited and a low travel range and low speed, they are not suitable for long distance transport.

4.7.2 Motorised transport

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

Motorised tricycles are the smallest type of low-cost motorised transport used to move FS. They vary in size and power and are able to access narrower streets than the larger motorised vehicles. Some models are capable of carrying loads of up to 1,000 kg. Sludge can either be transported in drums on the load bed of a tricycle (O’Riordan, 2009) or in a tank fitted to the back (Figure 4.14).

More expensive motorised transport equipment has also been used for the collection of FS. Examples include pick-up trucks with load capacities ranging from 2,000 to 5,000 kg, but these are not always affordable for small-scale service providers (McBride, 2012; Bhagwan *et al.*, 2012), sometimes trucks can be fitted with additional options such as cranes with hook lifts (Losai Management Limited, 2011).

4.7.3 Delivering faecal sludge to the treatment plant or transfer station

It is becoming more common for larger FSTPs to make use of mechanised receiving stations as shown in Figure 4.16, where the operator connects the hose from the vacuum truck to the input port, electronically signs in, and discharges the load through the system provided. The receiving station will track the time and date of the load, the volume received, the operator’s name, and any other relevant information as required. Mechanised receiving stations can therefore reduce human error and increase the accuracy and accountability of service providers. While mechanised receiving stations may be used for large operators, smaller systems and transfer stations rely on manual methods of vacuum truck emptying.



Figure 4.16 Automated faecal sludge receiving station at Manila Water's South Septage Treatment plant, Manila, Philippines (photo: WSUP, Sam Parker).

Independent of the delivery method of FS to the treatment plant or transfer station, operators should adhere to the following safety guidelines:

- 1 Check in with facility guard or operator.
- 2 Carefully following instructions regarding the sampling of FS. Some FSTPs have designated sites for residential septage, and others for commercial sludges. Plant operators may request samples of the FS prior to allowing discharge if it is suspected that the FS may contain materials hazardous to the plant.
- 3 Position the truck in the designated location for sludge removal, park and take the truck out of gear, apply the parking brake, and chock the wheels.
- 4 Remove the hose and make the connections.
- 5 Engage the power take-off or other mechanism for unloading the tank and complete the offloading process.
- 6 Obtain the necessary authorisation and access to the transfer station prior to transporting FS, as some transfer stations have locked inlets.
- 7 Ensure sufficient water is available for washing the solids as some transfer stations have screens to remove non-biodegradable solids.
- 8 Store any screened non-biodegradable solids in a safe location to drain and dry prior to containment and/or proper disposal either through incineration landfilling.
- 9 Use proper lifting techniques when discharging drums into a transfer station such as standing on a stable surface, and ensure all protective equipment is worn.
- 10 Clean up any spillage in the area around the inlet after completing the discharge of FS into the transfer station and re-seal the inlet.
- 11 Use personal protective equipment such as gloves and hard hats, and do not smoke during the entire collection and discharge operation.
- 12 Replace hoses and equipment, following adequate hygiene practices (e.g. hand washing), and completing the required paperwork.

4.8 TRANSFER STATIONS

4.8.1 Introduction

Earlier sections in this chapter introduced different options for the collection and transport of FS including small-scale equipment suitable for use in areas inaccessible to large vacuum tankers. While some of this equipment may be suitable for transporting sludge over short distances, the travel times are often too great for it to be economically viable for transporting FS to a final centralised treatment or disposal site.

In order to address this issue, decentralised transport approaches have been developed dividing the transport process into two main stages: primary and secondary. During the primary stage, carts or small vehicles are used to transport the FS from the point of collection to a nearby transfer station. In the secondary transport stage, the transfer station is emptied by means of large-capacity transport equipment such as a tanker truck, and transported to a final disposal point. It is essential that transfer stations be accessible to both primary and secondary transport equipment.

4.8.2 Types of transfer stations

There are two main types of transfer stations: 'fixed' and 'mobile'. These are described in more detail in the following sections.

Fixed transfer stations

Fixed transfer stations can be divided into four main categories, the first of which are 'permanent storage tanks'. Constructed as vault-like concrete structures, these tanks are designed to provide storage capacity for FS over a short period of time without capacity for treatment. An example of such tanks are the underground holding tank (UHT) reported by Boot (2007) in Accra, Ghana. With capacities of approximately 23 m³, the UHTs were designed to provide access to pan latrine collectors (primary transport) and vacuum trucks (secondary transport). However, the natural solid-liquid separation and siltation that takes place when FS is stored over relatively long periods soon became an operational issue for local authorities. As a result, many UHTs fell into disuse as de-silting became a prohibitively costly and time-consuming process.

To mitigate the challenges of de-silting, a second category, the 'modular transfer station' has been developed using portable containers to replace the concrete vault. These come in various sizes such as:

- small sized (e.g. 200-litre metal drums, McBride, 2012);
- medium-sized (e.g. Intermediate Bulk Containers (IBCs) made of plastic liner and metallic frame, 500 – 3,000 litres);
- large-sized (e.g. customised metallic tanks or skips, >2,000 m³ (Macleod, 2005; Strauss and Montangero, 2002).

The fixed transfer station essentially serves the role of a secure, safe, storage facility and can be designed according to the type of containers used. For example, in one project in Ghana a concrete-lined pit within a fenced compound was used to store the containers in order to avoid tampering, flooding or spillage. Once full the IBCs are emptied with a vacuum truck.

A third type of fixed transfer station is the 'multi-functional permanent tank'. In addition to providing storage capacity, it can also accept fresh FS from a public toilet, and/or provide partial sludge treatment. This latter design feature could include processes such as dewatering (settling tanks, drying beds, geotubes - ERE Consulting Group and Indah Water Konsortium, 2012) or anaerobic digestion (e.g. septic tanks, anaerobic baffled reactors, biogas digesters). The main advantage of stations providing both access to fresh FS and treatment capacity is easier siting due to acceptance by community and a

reduction in secondary transport fees due to dewatering. Furthermore, treatment byproducts (e.g. liquid effluent or biogas) could be used if further treatment is provided. An example of a transfer station with capacity for receiving fresh FS is provided in Case Study 4.2.

The fourth type of fixed transfer station is the 'network-connected station'. These types of stations provide direct or indirect access to the sewerage network, if one exists, for the secondary transport of FS and/or its liquid effluent. Utilities and asset owners rightfully discourage the use of manholes for sludge disposal as it can lead to increased blockages in the network due to the low water content of the FS and also high BOD loading at the wastewater treatment plant (Chapter 9). However, illegal dumping into the network is not uncommon generally due to a lack of alternative facilities and the ease of access.

Mobile transfer stations

Mobile transfer stations consist of easily transportable containers providing temporary storage capacity at any point near the structure being emptied - essentially a tank fitted on a wheeled chassis. Examples of such transfer stations include motorised collection vehicles, or tanker trailers pulled via a truck or tractor.

The stations are sited in any area where multiple trips by small-scale transport equipment are required. The main advantage of these stations is that they sidestep the complex and often lengthy procedures required for siting fixed stations in high-density settlements. They can also double as secondary transport containers once full as they can be easily driven or towed to the final disposal site.

If towed, the motorised vehicle towing the container is capable of performing other related or unrelated duties thus allowing for cost savings and potential for increased revenue. Such systems have reportedly been used in places such as Maseru, Lesotho (Strauss and Montangero, 2002).

4.8.3 Siting of transfer stations

In order to establish a successful multi-staged transport system using transfer stations, the siting of the stations needs to be carefully planned. The following section highlights important aspects that should be considered in the planning stages.

Optimising coverage

The coverage of transfer stations needs to be sufficient to meet the demand generated by sludge collection using small-scale equipment, while at the same time minimising the overall cost of primary transport. In order to determine the appropriate coverage of transfer stations, their sizing, and their proximity to one another, the cost of primary and secondary transport methods being used need to be taken into account. The provisional use of mobile stations may assist in optimising coverage by allowing the evaluation of the suitability of potential locations over a period of time without committing to the construction of a fixed station.

Land availability

The process of finding suitable land space and obtaining the relevant permission for transfer stations can be difficult and time consuming. This can sometimes involve lengthy negotiations with multiple governmental agencies and land owners, particularly when siting within informal settlements. Due to their non-permanent nature, mobile stations could potentially mitigate such challenges, or alternatively consideration could be given for the use of modular transfer stations with small footprints. However, it should be noted that without adequate legal assurances, service providers could be required to remove such stations by dissatisfied landowners.

Acceptance

It is not uncommon for communities to reject the siting of a transfer station in close proximity to their homes. This so-called 'Not-In-My-Back-Yard' (NIMBY) effect can be challenging in densely populated informal settlements where there is little, if any, open land. Such rejections have been reported in Dar es Salaam, Tanzania (Muller and Rijnsburger, 1992), Maputo, Mozambique (Godfrey, 2012) and Freetown, Sierra Leone. Early involvement of the communities in the siting process may therefore be necessary. Offering incentives such as combining transfer stations with other facilities like communal toilets and showers may help increase the level of acceptance.

Access

Depending on the type, access to a transfer station by primary and secondary transport vehicles or trunk sewers is necessary for proper operation. For instance, while siting a transfer station in the middle of a densely populated informal settlement would reduce the primary transport travel distance, it might not be accessible to larger vehicles used in secondary transport. It is thus necessary to ensure transfer stations are sited on roads large enough for access by secondary transport vehicles.

Case Study 4.2: Large capacity modular and multi-functional transfer station

A transfer station comprising a 6 m³ shipping container placed atop a salvaged 6 m³ tank container (ISO tank) was constructed by GOAL, Sierra Leone (Figure 4.16). The shipping container was customised to provide a disposal point for primary transport service providers, as well as one male and one female public sanitation facility. The disposal point was configured to receive sludge from 60-litre sealed drums through a screened chute connected to the tank container below. If and when necessary, the two containers can be disassembled, lifted with a crane and transported via a lorry to another location.

Water for the station was provided through a networked connection to a PVC water storage tank. This allowed for cleaning of the emptied 60-litre drums, as well as the installation of pour-flush toilets and hand washing facilities. The wastewater from the toilets was piped into the holding tank while the washing water was piped into a nearby soakaway. Access to the sanitation facilities was provided via a staircase and walkway, the latter being a necessity albeit one that limited access to those with reduced mobility.

Siting the station

A suitable site was identified on a piece of privately owned land, with the agreement that the station could be moved in the future if required. Obtaining the necessary permission from the local authorities was significantly easier than would have been for a fixed station, as the station was not legally classified as a permanent structure. Acceptance from neighbouring residents was also forthcoming as the station provided them with much needed toilet facilities. It has yet to be determined if the location is optimal for the primary and secondary transport service providers.

Performance

As of 2012 the transfer station was not yet operational and a management system had not been established. It is therefore difficult to evaluate performance, however some of the future potential challenges that have been identified include:

- the possibility that the land owner may require the demobilisation of the station, which would require a renewed siting process;

- the risk of public exposure to the sludge given the close proximity of the toilets to the disposal point;
- the difficulty of carrying the 60-litre drums up the stair case to the disposal point;
- the frequency of siltation and the need for de-silting the tank; and
- the cost implications of the potentially high volume of water entering the holding tank from the toilets.

Some of these issues might be addressed in the future, including providing a ramp dedicated for wheeling the drums to the disposal point, and providing dewatering capabilities.



Figure 4.17 Large capacity modular and multi-functional transfer station (top), and sanitation facility (bottom) (photo: GOAL).

4.9 OCCUPATIONAL HEALTH AND SAFETY

There are many specific health and safety concerns associated with the collection, transport, and discharge of FS. Unfortunately, the current situation is that the majority of FS collection and transport service providers in low-income countries do not practice adequate health and safety protection, particularly when employing manual emptying techniques or using small-scale equipment. As a result, service providers are at a high risk of exposure to physical, chemical and biological hazards. This section provides a brief summary of some of these hazards, and methods for reducing exposure. Additional health and safety information can be found in Chapter 11.

4.9.1 Physical hazards

The following physical hazards can exist in the handling of FS:

- low bearing capacity of the soil surrounding an unlined pit can lead to the collapse of its sidewalls during emptying (in particular for manual emptying);
- slips, trips and falls;
- exposure to sharp objects contained in the sludge (e.g. glass, metals);
- carrying heavy loads (e.g. containment structure cover or sludge-filled containers); and
- traffic (particularly relevant during transport).

4.9.2 Chemical hazards

The following chemical hazards are known to exist:

- direct and indirect oral, nasal and dermal exposure to chemicals (e.g. hydrocarbons that are introduced as odour suppressants, although this practise is not recommended);
- working in confined spaces in the presence of harmful gases (e.g. methane, ammonia, sulphur dioxide), in an oxygen depleted environment (in particular during manual emptying).

4.9.3 Biological hazards

The following biological hazards can exist in the handling of FS:

- direct and indirect oral, nasal and dermal exposure to multiple types of pathogens in FS (e.g. bacteria, viruses, protozoa, and helminthes – for more information refer to Chapter 2).

4.9.4 Other hazards

- pervasiveness of alcohol consumption in the FS collection profession (Godfrey 2012, Mikhael 2011).

4.9.5 Mitigating risks

Preventative measures for mitigating risks can be adopted voluntarily or, assuming effective enforcement measures are in place, through the introduction of regulation.

The first and best line of defence for mitigating risks is by limiting exposure to the previously defined hazards. This includes:

- provide and wear the appropriate personal protective equipment (PPE) to avoid direct and indirect exposure to FS (e.g. gloves, coveralls, rubber boots with a metal sole, safety glasses and safety masks);
- develop and provide training on the use of tools customised for local conditions and local containment systems in order to avoid direct contact with FS; and
- provide a training programme on standard operating procedures including the proper use of PPE, tools and equipment.

Preventative measures related to personal health care are recommended including immunisation, and a deworming program. The latter is recommended particularly for service providers transitioning from unsafe to safe practices.

4.10 CONCLUSION

Much has been achieved in the field of FSM to improve collection and transport practices. However, there are still significant gaps that will require innovative and practical solutions.

Many of the challenges faced with emptying onsite sanitation systems are related to or influenced by their design. For instance, a septic tank placed far from the road makes access by vacuum trucks more difficult. Sludge containment structures for toilets with water seals have much less non-biodegradable material (e.g. household solid waste, menstrual hygiene products, rags, and cloth) mitigating clogging during collection and thus making the process easier and more efficient.

Innovations for safer, more effective and more efficient collection and transport services need to consider improvements to existing containment structures, as well as developing future designs. For the implementation of new designs to be effective, a multidisciplinary approach is required, involving, a range of specialists including sanitation specialists, design engineers, promotion and marketing personnel, masons, and legal advisors.

From a technical perspective, some recommendations have been made for improvements to existing sanitation facilities to enable easier collection. One suggestion is the installation of a built-in suction pipe extending to the bottom of a pit latrine (Coffey, 2007). The pipe could be used to inject air and water at low pressures into the pit to fluidise the sludge, thereby allowing collection to start from the most dense and difficult-to-pump sludge at the bottom of the pit, to the least dense and easy-to-pump sludge at the top. This recommendation is supported by studies from Hawkins (1982) where it was suggested that the addition of 2% water to sludge could increase its fluidity by 30 to 300 times. While initial trials of this design were reportedly promising, there is no evidence of its large-scale promotion or adoption.

A further innovative method currently under investigation is the Omni-Ingester, being developed with funding by the Bill & Melinda Gates Foundation. The Omni-Ingester will be designed to separate water, sand, and trash from sludge followed by sanitation of byproducts in the collection truck, thereby reducing the need for transport to treatment plants, often the most expensive part of the service. Such technologies, when used in conjunction with community based FSM programs can provide transformative opportunities for wide scale sanitation improvement while considering the health and safety of the service provider.

4.11 BIBLIOGRAPHY

- Barreiro, W.C., Strauss, M., Steiner, M., Mensah, A., Jeuland, M., Bolomey, S., Koné, D. (2003). Urban excreta management - Situation, challenges, and promising solutions. In IWA Asia-Pacific Regional Conference.
- Bhagwan, J., Wall, K., Kirwan, F., Ive, O.M., Birkholtz, W., Shaylor, E., Lupuwana, N. (2012). Demonstrating the Effectiveness of Social Franchising Principles: The Emptying of Household VIPs, a Case Study from Govan Mbeki Village.
- Boesch, A., Schertenleib, R. (1985). Emptying On-Site Excreta Disposal Systems: Field Tests with Mechanized Equipment in Gaborone (Botswana). Duebendorf, Switzerland: International Reference Centre for Waste Disposal (IRCWD).
- Boot, N.L.D. (2007). Talking Crap: Faecal Sludge Management in Accra, Ghana. Water, Engineering and Development Centre (WEDC). Loughborough, UK: Loughborough University.
- BPD (2005). Sanitation Partnerships: Dar es Salaam Case Study. Dar es Salaam, Tanzania: Building Partnerships for Development.

- Brikké, F., Bredero, M. (2003). Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation. Report for World Health Organization and IRC Water and Sanitation Centre, Geneva, Switzerland.
- Buckley, C., Foxon, K.M., Brouckaert, C.J., Rodda, N., Nwaneri, C., Balboni, E., Couderc, A., Magagna, D. (2008). Scientific Support for Design and Operation of Ventilated Improved Pit Latrines and the Efficacy of Pit Latrine Additives. University of KwaZulu-Natal, Pollution Research Group, School of Chemical Engineering. Gezina: Water Research Commission.
- Chowdhry, S., Koné, D. (2012). Business Analysis of Faecal Sludge Management: Emptying and Transportation Services in Africa and Asia. Seattle: The Bill & Melinda Gates Foundation.
- Coffey, M. (2007). Propose and Test Pit Latrine Designs for Effective Emptying by Mechanical Exhauster. Newtownmountkennedy, Ireland: Manus Coffey Associates.
- De los Reyes, F. (2012). Hygienic Pit Emptying with Low Cost Auger Pump. Available from Sustainable Sanitation Alliance: <http://www.susana.org/images/documents/07-cap-dev/b-conferences/12-FSM2/c8.3-fsm2-de-los-reyes-north-carolina-state-university-usa.pdf>, accessed January 2013.
- ERE Consulting Group and Indah Water Konsortium (2012). Landscape Analysis and Business Model Assessment in Faecal Sludge Management: Extraction and Transportation Model in Malaysia. Seattle: The Bill & Melinda Gates Foundation.
- Godfrey, A. (2012). Faecal Sludge Management Demonstration Project in Maxaquene A and B, Maputo, Mozambique. Maputo: WSUP.
- GRET Cambodia. (2011). Landscape Analysis and Business Model Assessment in Faecal Sludge Management: Extraction & Transportation Models - Cambodia, Volume 1 – Main Report. Phnom Penh, Cambodia: Bill & Melinda Gates Foundation.
- Hawkins, P. M. (1982). Emptying On-Site Excreta Disposal Systems in Developing Countries: An Evaluation of the Problems. IRCWD News (17), p.1-9.
- IDEO (2012). Clean Team Brand Guide. San Francisco, California: IDEO.org.
- Losai Management Limited (2011). Landscape Analysis and Business Model Assessment in Fecal Sludge Management: Extraction and Transportation Models in Africa. Webster: The Bill & Melinda Gates Foundation.
- Macleod, N.A. (2005). The Provision of Sustainable Sanitation Services to Peri-urban and Rural Communities in the ethekuni (Durban) Municipality.
- MCA (2007). Operating and Maintenance Manual for UN-HABITAT MK III Vacutug Latrine Emptying Vehicle. Dublin, Ireland: Manus Coffey and Associates.
- McBride, A. (2012a). A Portable Pit Latrine Emptying Machine - The eVac. Pietermaritzburg, South Africa: PID, EWB-UK, WFP.
- McBride, A. (2012b). The eVac in Malawi. Blantyre, Malawi: PID, EWB-UK.
- Mikhael, G. (2011). Assessment of Faecal Sludge Emptying Services – Freetown, Sierra Leone. Freetown, Sierra Leone: GOAL Sierra Leone.
- Mikhael, G., Parkinson, J. (2011). Assessment of Financial Costs of Sludge Emptying Vacutug Services in Dhaka, Bangladesh (Unpublished). London, UK: Water and Sanitation for the Urban Poor (WSUP) and International Water Association (IWA).
- MSF (2010). Public Health Engineering in Precarious Situations. Médecins Sans Frontières (MSF).
- Muller, M. S., Rijnsburger, J. (1992). MAPET: A Neighbourhood-based pit emptying service with locally manufactured handpump equipment in Dar es Salaam, Tanzania. Gouda, The Netherlands: WASTE Consultants.
- O’Riordan, M. (2009). WRC PROJECT 1745 Management of sludge accumulation in VIP latrines Investigation into Methods of Pit Latrine Emptying. Durban: Partners in Development (Pty) Ltd.
- Still, D., Foxon, K. (2012). Tackling The Challenges of Full Pit Latrines Volume 1: Understanding sludge accumulation in VIPs and strategies for emptying full pits. Gezina: Water Research Commission.
- Still, D., O’Riordan, M. (2012). Tackling the Challenges of Full Pit Latrines Volume 3: The Development of Pit Emptying Technologies. Gezina: Water Research Commission.
- Strauss, M., Montangero, A. (2002). Faecal Sludge Management – Review of Practices, Problems and Initiatives. Dubendorf: EAWAG / SANDEC.

Tilley, E., Lüthi, C., Morel, A., Zurbrügg, C., Schertenleib, R. (2008). Compendium of Sanitation Systems and Technologies. Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (EAWAG).
 WASTE Consultants. (1993). Summary of the Comparative Study on Pit Emptying Technologies (COMPET). Dar es Salaam, Tanzania: WASTE Consultants.

Additional Reading Material

Boesch, A., Schertenleib, R. (1985). Emptying onsite excreta disposal system – Field Tests with Mechanized Equipment in Gaborone (Botswana). International Reference Centre for Waste Disposal (IRCWD). (IRCWD report; no. 03/85). Dübendorf, Switzerland: International Reference Centre for Waste Disposal.
 O’Riordan, M. (2009). Investigation into methods of pit latrine emptying – Management of sludge accumulation in VIP latrines. Water Research Commission (WRC), South Africa
 Still, D., Foxon, K., O’Riordan, M. (2012). Tackling the challenges of full pit latrines – Volumes 1 to 3. WRC Report No. 1745/1/12, Water Research Commission, South Africa.

End of Chapter Study Questions

1. List four manually operated mechanical collection technologies and describe how these systems work.
2. What technical challenges are often encountered in the operation of the Gulper System?
3. Explain what transfer stations are, and describe two types of transfer stations.
4. Name three types of hazards in the collection and transport of FS, and how to mitigate them.