CAWST
Centre for Affordable Water and Sanitation Technology

Technical Brief: Sanitation System – Emptying and Transporting Fecal Sludge

Sanitation System

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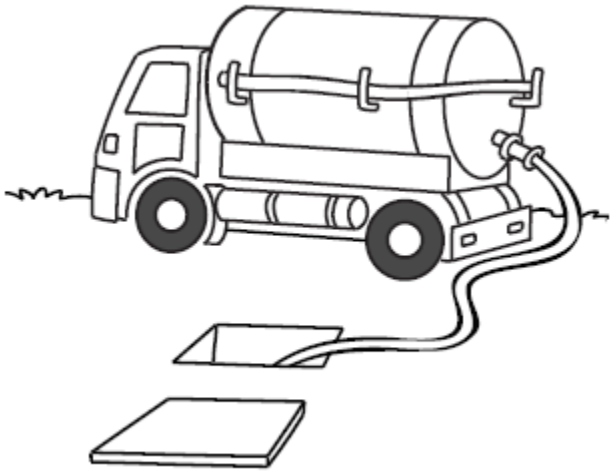


CAWST

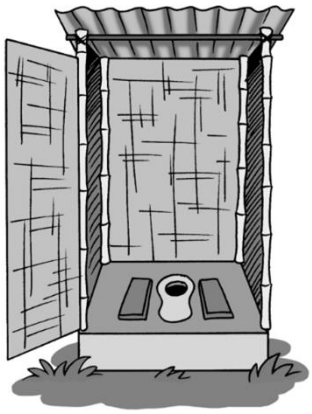
Technical Brief: Sanitation System – Emptying and Transporting Fecal Sludge

1 Introduction

A sanitation system deals with human excreta from the time it is generated until it is used or disposed of safely. The third component of a sanitation system addresses safely emptying fecal sludge from on-site sanitation technologies, and then transporting the sludge for treatment, use or disposal.

Emptying (also called collection) and transporting fecal sludge is a critical link in a sanitation system. Great efforts are being made globally to reduce open defecation by building on-site sanitation technologies, like pit latrines and septic tanks. However, it is not enough to only build an on-site technology to ensure good sanitation and protect public health. The technologies will eventually fill up with fecal sludge. Yet, emptying full technologies and safely managing the fecal sludge is an essential service that is often neglected. 2.7 billion people around the world use on-site sanitation technologies that need fecal sludge management services (Strande, Ronteltap & Brdjanovic, 2014).

Some on-site sanitation technologies, like septic tanks and aqua privies, are designed to be emptied periodically. For other technologies, like pit latrines, people need to decide whether to empty the pit or dig a new one. Emptying is a common practice in densely populated areas where households are not connected to a sewered system or do not have the space to dig a new latrine pit when the old one is full.



On-site sanitation technologies, like a pit latrine, will eventually fill up with fecal sludge

Ideally, well-equipped and protected service providers should empty on-site sanitation technologies and transport the sludge to a treatment, use or disposal site. However, in reality, many on-site technologies are either abandoned or emptied using unsafe and unhygienic methods. Fecal sludge is simply dumped by the home, in the street, or in nearby water sources.

Emptying and transporting fecal sludge can be made more efficient and safe for sanitation service providers, households, communities, and the environment. This Technical Brief introduces the health and safety concerns, and different methods to efficiently and safely empty and transport sludge from on-site sanitation technologies.

CAWST focuses on the planning, design, and implementation of on-site sanitation projects for low-income communities not connected to a sewer. For such communities, household or decentralized sanitation offers a hygienic and affordable solution.

CAWST's free, open content resources and schedule of international training workshops can be found at: https://resources.cawst.org and www.cawst.org/training.

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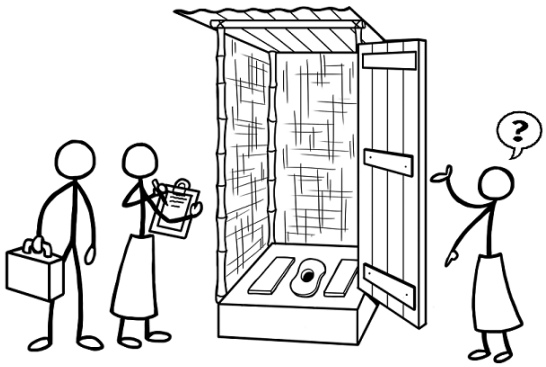
2 Service Provision

There are a range of service providers for fecal sludge emptying and transport, from informal and independent individuals to formal and large companies. In some areas, services are also provided by public utilities or nongovernmental organizations (Chowdhry & Kone, 2012). It is common to see a variety of service providers working in the same region due. This is because of the complexity and accessibility of different on-site sanitation technologies and the customers' ability to pay for the services (Strande, Ronteltap & Brdjanovic, 2014).

Regardless of who provides the service, they should perform the following tasks when visiting a household (Strande, Ronteltap & Brdjanovic, 2014):

1. Go to the household and bring the required equipment.
2. Meet the customer to arrange logistics and inform them of the service.
3. Tell them the fee or negotiate with the customer, depending on the business model.
4. Put on personal protective equipment (like gloves, boots, masks, and protective clothing).
5. Locate the on-site sanitation technology.
6. Determine the access point of the on-site sanitation technology.
7. Open the on-site sanitation technology cover.
8. Remove solid waste, if necessary.
9. Empty the on-site sanitation technology.
10. Evaluate the condition of the on-site sanitation technology.
11. Close and secure the on-site sanitation technology.
12. Clean the areas around the on-site sanitation technology.
13. Do a final inspection and report any issues to the customer.
14. Transport the fecal sludge to a treatment or disposal facility.

As well, service providers can provide valuable information to their customers and answer any questions. Local governments should work with service providers to distribute information about their on-site sanitation technology, the importance of fecal sludge management, and good hygiene practices. Service providers can hand out, for example, pamphlets on the importance of maintaining and emptying on-site sanitation technologies.



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3 Emptying Technologies

There are two ways to empty sludge from an on-site sanitation technology:

1. Manual emptying (using a bucket or hand pump)
2. Mechanized emptying (using a mechanized pump or vacuum truck)

The advantages and limitations of each method are summarized in the following table and described in the next sections.

Table: Advantages and Limitations of Manual and Mechanized Emptying

Method	Advantages	Limitations
Manual emptying	• Potential for local job and income generation • Simple hand pumps can be built and repaired with locally available materials • Low capital costs • Provides service to difficult to access on-site sanitation technologies • More affordable service for the poor	• Hard and unpleasant work • Increased health risks to emptiers from exposure to fecal sludge • Increased safety risks to emptiers from entering pits and tanks • Increased public health and environmental risk from spilt fecal sludge • Time consuming, can take several days depending on the size of the technology • Bad smells
Mechanized emptying	• Potential for local job and income generation • Fast and generally effective fecal sludge removal • Reduced health, safety and environmental risks	• High capital, operating and maintenance costs • Not all parts and materials many be locally available • Not all households may be able to afford the service • May have difficulties to access on-site sanitation technologies (for example, narrow roads) • Cannot pump thick sludge (must be thinned with water or manually removed) • Pumps can usually only suck down to a depth of 2–3 metres, cannot completely empty deep technologies • Pump must be located within 25 metres of the technology

(Adapted from Strande, Ronteltap & Brdjanovic, 2014; Tilley, Ulrich, Luthi, Reymond & Zurbrugg, 2014; WaterAid, 2013)

Whether on-site sanitation technologies are emptied manually or with mechanized equipment, owners can make it safer to empty in the following ways:

- Fully lining latrine pits to prevent the walls from collapsing when emptied. See CAWST's latrine design and construction materials for more information on pit lining.
- Building two (twin) latrine pits, so the contents of one pit are left to degrade while the other pit is being used. This makes the fecal sludge safer to handle when it is time to empty the pit.

- Not disposing solid waste into the latrine. Fecal sludge mixed with garbage can be impossible to empty using motorized equipment. Garbage such as glass, medical waste or sharp objects are significant health and safety risks to the people emptying the on-site sanitation technologies and treating the sludge.

3.1 Manual Emptying

Manual emptying is typically done in low-income areas and informal settlements that are inaccessible by mechanical equipment and trucks. A recent survey of 30 cities in Africa and Asia found that about one-third of households manually empty their on-site sanitation technologies. While family members sometimes do this job themselves, a manual emptier is hired almost 90% of the time (Chowdhry & Kone, 2012).

As well, some on-site sanitation technologies can only be emptied manually. For example, composting latrines and dehydrating latrines must be emptied with a shovel. This is because the material is solid and cannot be removed with a vacuum or a pump.

There is a social stigma attached to manual emptying. People willing to do this kind of work are often the poor and disadvantaged in need of additional income. Manual emptying is hard and unpleasant work, and it poses serious health and safety risks if it is not carefully managed. The tools used for manual emptying are simple, usually no more than a bucket, shovel, and rope. Workers often use minimal or no personal protection, like gloves or boots, to prevent direct contact with the fecal sludge. As a result, they report injuries, skin rashes, and other diseases (Chowdhry & Kone, 2012; Opel, 2012).

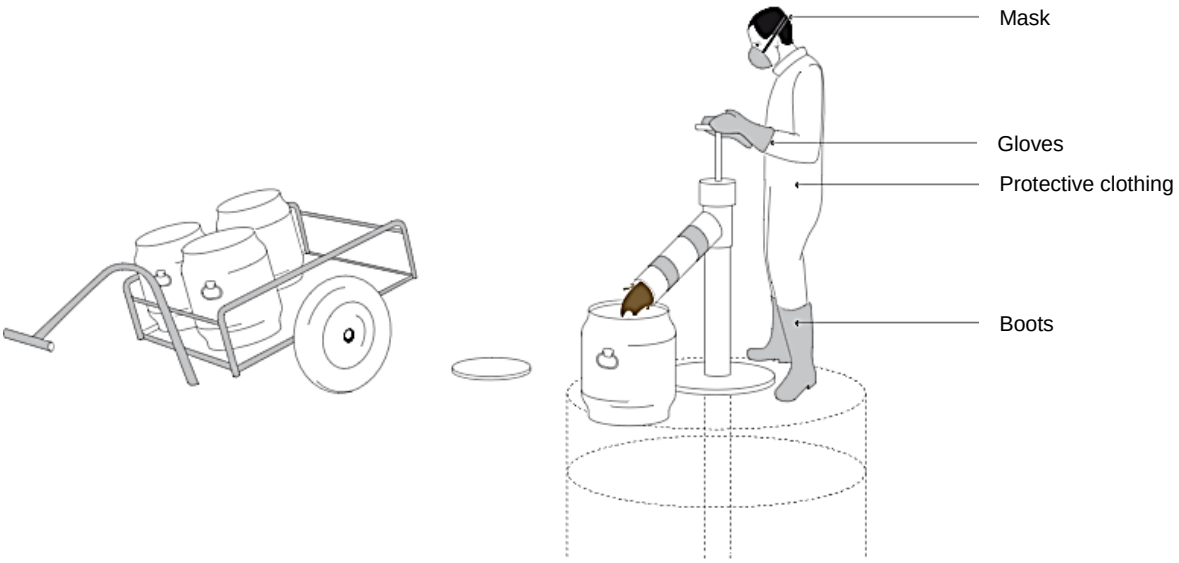
Workers (or the householders doing the work) need to understand the risks of emptying on-site sanitation technologies and handling fecal sludge. They must know to take health and safety precautions, such as:

1. Wear gloves, boots, protective clothing, and masks while emptying the pit. Wash hands and body with soap afterwards.
2. At least part of the slab or cover will have to be removed to allow access and improve air circulation. The on-site sanitation technology should be allowed to vent for a while before anyone begins work. Venting lets harmful gases (like methane, ammonia, and sulphur dioxide) escape and fresh air to enter.
3. No one should enter a pit without a harness and safety rope. There should be two people holding the rope who can pull the worker out if they are overcome by gases or if the pit walls collapse.

Some portable, manually operated pumps have been developed to improve the efficiency of manual emptying and better protect the health and safety of workers. Some of these technologies include the:

- Manual diaphragm pump: Workers push and pull the handle of the hand pump. The fecal sludge is pumped up through the main shaft and discharged through a spout.

- Manual pit emptying technology (MAPET): The hand pump is connected to a vacuum tank mounted on a pushcart. When the hand pump is turned, air is sucked out of the vacuum tank and sludge is sucked up into the tank.
- Gulper: Works on the same concept as a water pump. When the handle is pumped, the sludge rises up through the bottom of the pump and is forced out of a spout.



Using a manually operated pump (Credit: Tilley et al., 2014)

Manual emptying technologies have experienced various technical and implementation challenges. For instance, some pumps clog with sludge that contains household solid waste, which is commonly found in pit latrines. As well, some are not designed with locally available pumps or spare parts, and rely on importation.

Of all the manual emptying technologies, the Gulper has reached the widest number of pit emptying service providers in Asia and Africa. This is mainly due to strong interventions from external organizations, like nongovernmental organizations (NGOs), that provided funding, training and technical support (Strande, Ronteltap & Brdjanovic, 2014).

Design Tip

Manually emptying sludge (with buckets and a shovel) from pits deeper than 1.5 metres is impossible, unless the emptier climbs inside the pit, which is a serious health and safety risk. A compromise must be made between the pit depth and the frequency and difficulty of emptying. Shallow pits (less than 1.5 metres deep) are easier to empty and have less health risks to emptiers than deeper pits, but they need to be emptied more often.

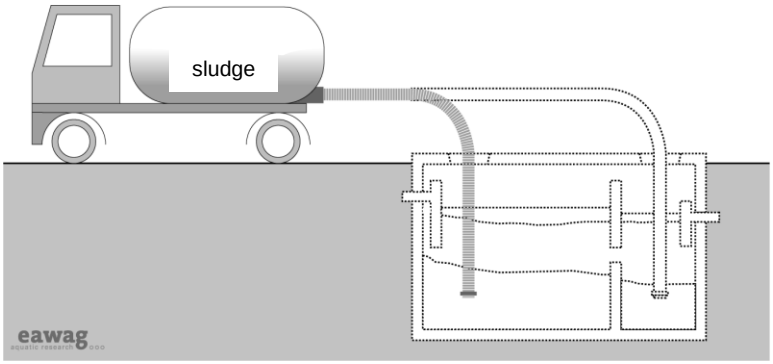
(Buckley et al., 2008; Still & Foxon, 2012; Tilley et al., 2014)

3.2 Mechanized Emptying

Mechanized fecal sludge emptying technologies are powered by electricity, fuel or pneumatic systems (using pressurized air or gas).

Vacuum pumps are effective in emptying water-based on-site sanitation technologies, like pour flush latrines, septic tanks, and aqua privies. The pump is connected to a hose that is lowered through an access cover into the technology. The fecal sludge is then pumped into the storage tank mounted on a heavy duty truck or trailer, on lighter carts, or even human powered carts for smaller volumes (Strande, Ronteltap & Brdjanovic, 2014).

Vacuum trucks are available in a wide variety of sizes and models to meet different needs. Most commonly they have a storage capacity of 200 to 16,000 litres. Conventional vacuum trucks can hold as much as 55,000 litres (Strande, Ronteltap & Brdjanovic, 2014).



Emptying a septic tank with a vacuum truck (Credit: Tilley et al., 2014)

Mechanized emptying can be a fast and efficient way to empty on-site sanitation technologies, especially large tanks. It is also much safer and healthier for the service providers compared to manual emptying methods. Service providers need to operate the pump and move the hose, but they do not need to enter the technology or have direct contact with the fecal sludge.

However, there are some technical limitations for using vacuum trucks. Conventional vacuum trucks can usually only suck down to a depth of 2 to 3 metres. They also must be parked within 25 metres of the on-site sanitation technology, depending on the strength of the pump (Strande, Ronteltap & Brdjanovic, 2014). As well, large vehicles are often unable to access narrow streets and poor roads, especially in unplanned and informal communities.

Vacuum trucks are also designed for emptying water-based technologies, such as pour flush latrines, septic tanks, and aqua privies. Depending on the technology, the sludge can become too thick and cannot easily be pumped. In this case, it is necessary to dilute the fecal sludge with water so that it can flow more easily. However, this is inefficient and potentially costly. If water is not available, then manual emptying may be the only option to empty the technology (Tilley et al., 2014).

Other challenges of using conventional vacuum trucks include:

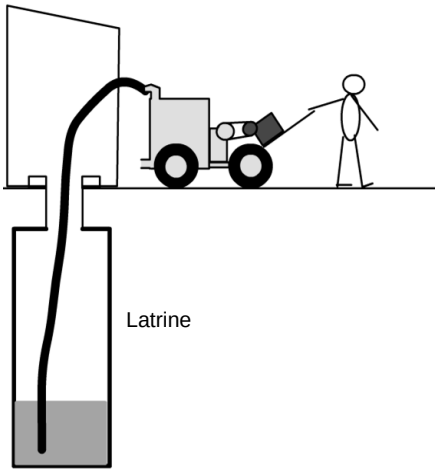
- Most are manufactured in North America or Europe, so they are expensive to import and buy locally.
- It is difficult to locate spare parts and a local mechanic to repair broken pumps and trucks.
- Poor households often cannot afford the services.

Smaller, mobile, and inexpensive pumps and vehicles have been developed to help overcome the challenges of using a large vacuum truck. However, none these technologies are yet used at scale.

For example, UN-HABITAT started the Vacutug project in 1995. It requested a design for a motorized system that could be:

- Manufactured locally
- Affordable
- Easily serviceable
- Able to operate in narrow streets
- Capable of pumping out dense sludge from on-site sanitation technologies

At the same time, sludge must be emptied as safely as possible without causing further health issues to the workers and the community. It has been tested by the UN and various nongovernmental organizations (NGOs) in some African and Asian countries; however, large-scale production and distribution of the Vacutug on a global scale has yet to start (UN-HABITAT, n.d.).



Small portable pump for pit emptying
(Credit: UN-Habitat, n.d.)

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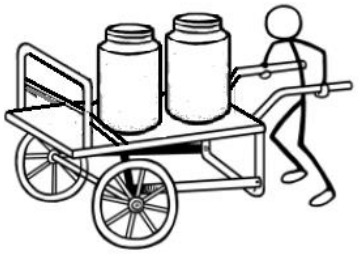
4 Transportation Methods

A safe method for transporting the fecal sludge must also be arranged. Similar to emptying, transport technologies can be classified into two categories:

1. Manual using human or animal power
2. Motorized using a fuel-powered engine

Manual service providers generally use simple, low-cost transportation methods that rely on human or animal power, such as a:

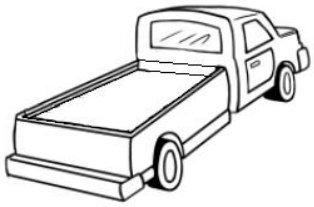
- Cart
- Wheelbarrow
- Wagon
- Rickshaw



Manual service providers often use open containers to transport the fecal sludge. The sludge should be put into covered containers with tightly fitting lids to reduce the risk of spills when it is transported.

Containers of sludge with capacities of up to 200 litres can be transported using manual push or pull carts. The carts are designed to fit into tight spaces and can transport fecal sludge about 500 metres, and sometimes up to three kilometres (Strande, Ronteltap & Brdjanovic, 2014).

Larger-scale manual emptying operations may be able to afford a small pick-up truck or other motorized vehicle to transport fecal sludge a further distance away. Motorized tricycles are the smallest type of low-cost motorized vehicle used to move sludge. They vary in size and power, and are able to access narrower streets than larger trucks. Some tricycles can carry up to 1,000 kg of sludge; whereas pick-up trucks can transport between 2,000 to 5,000 kg at one time (Strande, Ronteltap & Brdjanovic, 2014).



Both manual and motorized transportation methods face various challenges related to the following:

- **Road width and slope**: In densely populated areas roads can be narrow. Certain vehicles are not able to access the roads to service households. Steep slopes also reduce the accessibility of households.
- **Poor road construction**: It is difficult and dangerous for certain vehicles to use roads that are not maintained. Holes in the road, for example, could tip over a cart or pick-up truck. Pedestrians could be hurt and fecal sludge could spill onto the streets.
- **Accessibility in rainy season**: Roads can flood during a rainy season. Vehicles may not be able to pass through the flooded roads.

- **Traffic**: In urban areas, traffic is often dense and dangerous. Larger vehicles are more likely to get stuck in traffic. Smaller vehicles need to be particularly attentive to other vehicles.
- **Breakdown and repair**: Vehicles often breakdown and need to be repaired. The skills, tools, and spare parts to repair a vehicle are often not available or are expensive.
- **The weight of fecal sludge**: Fecal sludge is heavy, which limits how much sludge can be carried. It also makes it expensive to transport sludge over a long distance.
- **Risk of theft, damage and abuse**: This risk applies to all vehicles, including vehicles transporting sludge.

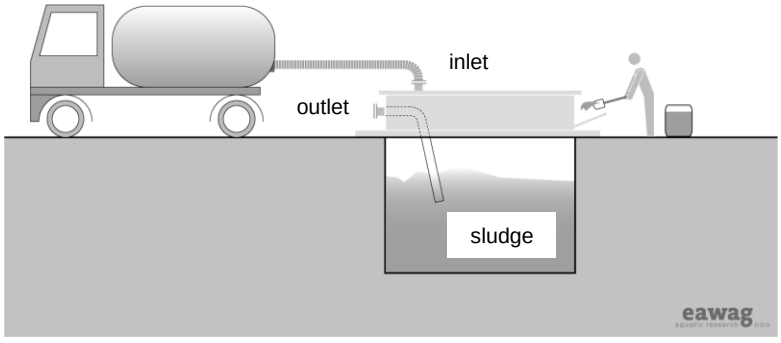
Vacuum trucks or other large vehicles with storage tanks are generally able to transport sludge directly to the treatment, use or disposal facility. However, due to the challenges for manual service providers to transport sludge, a common practice is to dump or bury the fecal sludge near the home, or dispose it in the local sewer system. However, moving the sludge just a few metres away from where it was collected does not provide a sustainable or hygienic solution for sludge disposal.

What About Disposing Fecal Sludge in the Sewer System?

Fecal sludge should not be disposed of in the sewer system. Yet, illegally dumping fecal sludge into the sewer system is common in low-income countries because it's easy to access and there are usually no other disposal options. Fecal sludge has a higher solids content than wastewater and it can clog the sewers. As well, it can lead to severe disruptions of the wastewater treatment facility. This is because fecal sludge has different characteristics than wastewater. See CAWST's Technical Brief: What is Fecal Sludge for more information on the differences between fecal sludge and wastewater.

(Strande, Ronteltap & Brdjanovic, 2014)

Transfer stations are an option when fecal sludge cannot be easily transported over a long distance. Transfer stations are fixed (permanent) or mobile (temporary) places to dispose of and store sludge. When the transfer station is full, a vacuum truck empties the sludge and takes it to a treatment or disposal facility. Easy and affordable access to a transfer station may help to reduce the incidence of illegal sludge dumping and encourage households to empty their on-site sanitation technologies more regularly. Transfer stations are still in the stage of innovative technology without actual field experience in developing countries other than a few pilot projects.



Manual service providers can dispose of fecal sludge in a local transfer station (Credit: Tilley et al., 2008)

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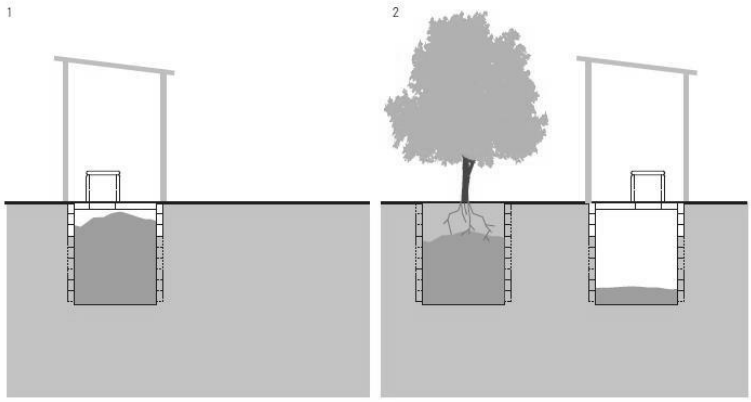
5 Relocating Latrines

Some on-site sanitation technologies, like pit latrines and ventilated improved pit (VIP) latrines, can be relocated when the pit is full. To decommission or close a pit, it can simply be filled with soil and covered. The full, covered pit poses no immediate health risk, and the fecal sludge will degrade naturally over time (Tilley et al., 2014).

Other latrines are specifically designed to be relocated when the pit is full. For example, the Arborloo latrine uses a shallow pit for storing fecal sludge that is filled and covered with soil when the pit is full. A tree is then planted on top of the filled pit which can grow well in the nutrient-rich soil. The superstructure, slab and footing are portable and are moved to a new pit. For more information, see the CAWST's Sanitation Fact Sheet: Arborloo Latrine.



Arborloo latrine (Credit: Tilley et al., 2014)

Households need to decide whether to empty the latrine pit to reuse it or dig a new one. Filling and covering pits is an adequate solution when emptying is not possible and when there is space to continuously re-dig and fill pits. Latrine emptying is a common practice in peri-urban and urban communities where households do not have sewered systems or the space to dig a new pit when the old one is full.

Table: Advantages and Limitations of Latrine Relocation

Advantages	Limitations
• Less expensive than paying for emptying services • Low risk of pathogen transmission since households do not come in contact with the fecal sludge • For Arborloo latrines, planting a tree can reforest an area, provide a sustainable source of food, and prevent people from falling into old latrine pits	• Needs space to regularly dig a new pit • Time consuming • Labour intensive • May not be socially acceptable to use fecal sludge to grow trees or food depending on the local culture

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6 Risk Management

Fecal sludge must be emptied and transported in a way that protects service providers, households, communities, and the environment. Fecal sludge is a major source of pathogens, such as bacteria, viruses, protozoa and helminths that cause disease. As well, emptying fecal sludge can also pose safety risks, such as:

- Workers being buried by walls collapsing in unlined latrine pits
- Injury from garbage disposed in the on-site sanitation technology
- Workers breathing in harmful gases in the on-site sanitation technology

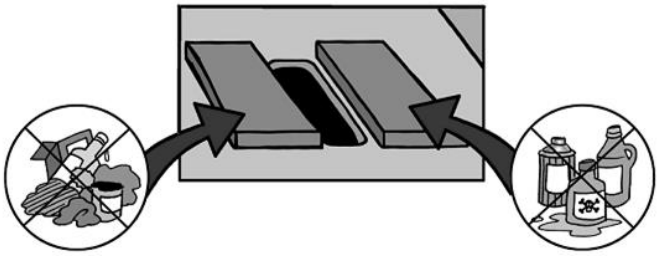
There are many protective measures (also called barriers) that should be put in place when emptying and transporting fecal sludge. This is often known as a multi-barrier approach. The following table shows barriers that can be used to avoid the spread of pathogens and protect public health.

Table: Protective Measures for Emptying and Transporting Sludge

Barriers to Protect Health		Action
	Use protective equipment	Wear protective equipment, such as clothing, gloves, boots, and mask. Clean and disinfect the equipment used.
	Wash hands	Wash hands with soap after handling fecal sludge, tools, and equipment.
	Clean tools	Disinfect the tools used for emptying and transport, and only use them for this activity. Safely store the tools so people do not touch them or use them for another purpose.
	Use containers with lids	Use an undamaged container with a tight fitting lid to prevent fecal sludge from spilling during transportation.
	Keep site clean	Clean the area where fecal sludge may have spilled.
	Train	Train service providers on proper emptying and transport procedures and hygiene practices. Train local community on the importance of regular emptying and the importance of not putting solid waste into the latrine.
	Deworm	Provide treatment for helminth infection to service providers and their families to stop the cycle of transmission and reduce helminths in fecal sludge.

Latrines Used as Garbage Dumps

Research on VIP latrine use in South Africa has shown that people often dispose of garbage into their pits when there is no proper solid waste management system. Solid waste may include menstrual hygiene products, condoms, health care waste (such as used needles), paper, metal, glass and organic material (such as kitchen and garden waste). (Buckley et al., 2008; Still and Foxon, 2012). Solid waste often needs to be "fished" out of the latrine before it can be emptied. This is time-consuming and a very messy job.



Alternative latrine technologies that make sludge easier to empty and safer to handle can also be used. Examples include twin pit latrines or latrines with aboveground chambers that have an access door to remove sludge. Twin pit latrines use two alternating pits; one pit is used for two years (or longer) and then covered while the other is used. Generally, after a two-year storage period the pathogens have been reduced and the fecal sludge is safer to handle. Pit latrines and VIP latrines can be constructed with twin pits. Building two pits, however, requires extra land space and for households to make a greater financial investment.

See CAWST's Sanitation Fact Sheets and Latrine Construction Manual for more information about the design and safety of different technologies.

7 Definitions

Characterization: Describing the biological, chemical, and physical properties of fecal sludge.

Excreta: Urine and feces that are not mixed with any flush water.

Fecal sludge: Also called sludge. Excreta from an on-site sanitation technology (like a pit latrine or septic tank) that may also contain used water, anal cleansing materials, and solid waste.

Fecal sludge management: Includes the emptying, transport, treatment, and safe use or disposal of fecal sludge from an on-site sanitation technology (like a pit latrine or septic tank). Some people also include storage in the definition of fecal sludge management.

Informal settlements: Unplanned residential areas that have been constructed where residents do not own the land, and housing is not in compliance with planning or building regulations.

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Non-sewered system: Also called on-plot or on-site sanitation. A sanitation system in which excreta and used water are collected and stored on the location where it is produced. Often, the fecal sludge has to be transported off-site for treatment, use or disposal.

On-site sanitation technology: Also known as a latrine. An on-site sanitation technology is made up of the parts included in the first two components of a sanitation system: user interface and excreta storage. Excreta is collected and stored where it is produced (for example, a pit latrine, septic tank, aqua privy, and non-sewered public toilets). Often, the fecal sludge has to be transported off-site for treatment, use or disposal.

Sewered system: Also called a sewer system, sewerage system, sewers, connected sanitation, and networked sanitation. A sanitation system that transports wastewater through a pipe network (like a simplified sewer, solids free sewer or conventional sewer) to another location for treatment, use or discharge. This includes centralized systems and decentralized wastewater treatment systems.

Treatment: Any process to inactivate pathogens, stabilize, dewater, or manage nutrients in fecal sludge.

8 Additional Resources

CAWST Sanitation Resources. Available at: https://resources.cawst.org/

- CAWST's education and training resources are available on a variety of sanitation topics including environmental sanitation; latrine design, siting and construction; fecal sludge management; and sanitation project implementation.

Faecal Sludge Management: Systems Approach for Implementation and Operation. Strande, L., Ronteltap, M. & Brdjanovic, D. (2014). London, UK: IWA Publishing. Available at: www.sandec.ch/fsm_book

- This is the first book dedicated to faecal sludge management. It summarizes the most recent research in this rapidly evolving field, and focuses on technology, management and planning. It addresses faecal sludge collection and transport, treatment, and the final end use. The book also goes into detail on operational, institutional and financial aspects, and gives guidance on integrated planning involving all stakeholders. It is freely available online in English and Spanish, and is coming out in French in 2017.

Compendium of Sanitation Systems and Technologies. Tilley, E., Ulrich, L., Lüthi, C., Reymond, P. & C. Zurbrügg (2014). 2nd Revised Edition. Eawag: Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland. Available at: www.eawag.ch/forschung/sandec/publikationen/compendium_e/index_EN

- The Compendium presents the concept of sanitation systems together with detailed information about sanitation technologies for each component of sanitation systems. The document targets engineers, planners and other professionals who are familiar with sanitation technologies and processes. However, it is also a useful document for non-experts to learn about the main advantages and limitations of different technologies and the appropriateness of different systems.
- The e-Compendium, is an online, interactive version of the Compendium, complete with a tool for combining technologies into a complete sanitation system. Available at: http://ecompendium.sswm.info/

Investigation into Methods of Pit Latrine Emptying. O'Riordan, M. (2009). Management of Sludge Accumulation in VIP Latrines. WRC Project 1745. Pretoria, South Africa: Water Research Commission. Available at: www.susana.org/en/resources/library/details/1424

- Includes an overview of several manual and mechanized pit emptying technologies.

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Calgary, Canada
Website: www.cawst.org Email: support@cawst.org
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