A Practical Guide to Available Pit-Emptying Technologies

Tom Gurski, Carbyne Enterprises, Inc., with
Sarah Hennessy, Triangle Environmental,
Tate Rogers, Triangle Environmental,
Jon Shaw, Jon Shaw and Associates

Version 2.0
Date: 22 June 2022

Table of Contents

Document Overview

PURPOSE

To provide an overview of available pit-emptying technologies and their application.

INTENDED AUDIENCE

Individuals and organizations with little or no sanitation experience.

GAP IN CURRENT LITERATURE

Most papers, articles, and guides are academic in nature and the information they provide is very granular.

This document is intended to be a practical guide and focuses on technologies that are readily available.

DOCUMENT USAGE

While usable in paper or pdf format, the document contains internal and web links that should be active in most pdf software.

Emptying the latrine

There are several types of non-sewered sanitation systems that store waste and must be emptied, including:

PIT LATRINE

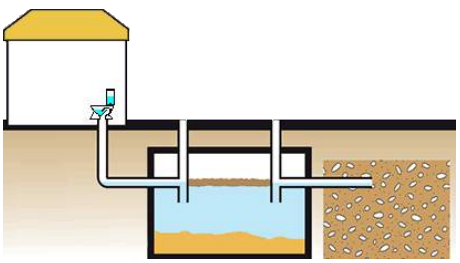
- A simple vault with a drop hole
- Vault can be lined or unlined
- Can produce very thick sludge

FLUSH LATRINE/ CESS PIT

- A simple vault with water used for flushing
- Vault is usually lined
- Usually produces thin sludge

SEPTIC TANK

- Water used for flushing
- A lined vault with a system to discharge effluent
- Sludge concentrates over time
- Can produce both thick and thin sludge



Issues affecting emptying

ACCESS TO PIT

Many systems are located deep within crowded settlements and cannot be accessed by trucks or large equipment

SLUDGE THICKNESS

Ranges from water-like to clay-like (water can be added to fluidize thick sludge), and one pit can have the entire range if highly stratified

TRASH

Pit latrines are often used as solid waste receptacles, which can cause clogging or damage to pump systems

ACCESS TO VAULT

Access hatch – built for the purpose of emptying

Aperture – access through drop hole or by removing toilet/pan

No access – hole must be dug or drilled

TRANSPORTATION

Sludge must be transported to an appropriate facility for disposal or treatment, which may or may not exist

COST

Many pit owners are severely disadvantaged and may be unable to pay for services

LEGAL/REGULATORY

Many governments are restricting practices that pose risk to service providers, the public, or the environment

Selection Table

	Use Case Factors													
System	Not truck-accessible	Not tractor-accessible	Long distance to road	Thin or medium-thin sludge	Medium sludge	Medium-thick sludge	Thick sludge	Significant trash	Small aperture	Small purchase budget	Small operating budget	Cleanliness sensitivity	Speed required	No. Operators Recommended (Including Drivers)
Vacuum truck	-	-	-	++	+	-	-	+	++	-	-	++	++	2
ROM	+	-	-	++	+	-	-	+	++	-	+	++	++	2
PITVAQ (eVac)	++	++	+	++	++	+	-	+	++	+	+	+	+	3
Minivac	++	++	+	++	++	+	-	+	++	+	+	+	+	3
PuPu Pump	++	++	+	++	++	+	-	+	++	+	+	+	+	4
Supavac/SolidsVac	++	++	++	++	++	+	-	+	++	-	-	+	++	2
Mobile HoneyWagon*	+	-	-	++	+	-	-	-	++	+	+	++	+	2
Trailer/pickup pump system*	+	-	-	++	+	-	-	-	++	+	+	++	+	2
Grinder pump to truck	++	++	++	++	+	-	-	+	-	+	++	+	++	2
Grinder pump to containers	++	++	+	++	+	-	-	+	-	+	++	+	+	3
Trash pump to truck	++	++	-	++	-	-	-	+	++	+	++	+	++	2
Trash pump to containers	++	++	+	++	+	-	-	+	++	+	++	+	+	3
Progressive cavity pump to truck*	++	++	++	++	++	+	-	-	++	+	+	+	+	2
Progressive cavity pump to containers*	++	++	+	++	++	+	-	-	++	+	+	+	+	3
Flexible impeller pump to truck*	++	++	+	++	+	-	-	-	++	+	+	+	+	2
Flexible impeller pump to containers*	++	++	+	++	+	-	-	-	++	+	+	+	+	3
Gulper to containers	++	++	+	++	++	+	-	-	++	++	++	+	-	4
Shovels, buckets to containers	++	++	+	++	++	++	++	++	+	++	++	-	-	4
Sludge digger to containers	++	++	+	-	++	++	+	+	+	++	++	-	-	4

Legend	
++	Well suited, operates as intended
+	Operates with reduced performance or additional issues
-	Not suitable

Full version of the Selection Table can be downloaded here.

*These systems are available in a range of configurations, types, sizes, and powers. Performance relative to these use case factors may be better than indicated in some instances

Table use case factors

FACTOR	DESCRIPTION	FACTOR	DESCRIPTION
Not truck-accessible	A large vehicle cannot reach pit	Significant trash	Pit contains trash that may affect pumping systems
Not tractor-accessible	A small vehicle (tractor and trailer, small pickup truck) cannot reach pit	Small aperture	Access to the pit is through a small hole
Long distance to road	The receiving vehicle is far from the pit (50+ m), or up significant elevation (5+ m)	Small purchase budget	Strong preference for less expensive equipment ($, $$)
Thin or medium-thin sludge	See definitions	Small operating budget	Strong preference for equipment that is less expensive to operate
Medium sludge	See definitions	Cleanliness sensitivity	Small spills, drips, etc. are unacceptable
Medium-thick sludge	See definitions	Speed required	Pits must be emptied quickly, requiring medium (50-150 liters/min) or fast (150+ liters/min) transfer to road
Thick sludge	See definitions	No. of operators needed, including drivers	Minimum number of staff required per emptying team

Vacuum Trucks

Purchase price	$$$$ (up to $200,000 new)	Thin	Fast
Energy source	Engine	Medium-thin	Fast
Power	High	Medium	Slow
Energy efficiency	Medium	Medium-thick	Slow
Flow rate	High	Thick	No

Definitions

OVERVIEW:
A truck with a large water vessel and a vacuum pump to draw vacuum in the vessel.
A suction hose is used to extract fluid from a source, filling the vessel.

OPERATING THEORY:
The engine of the truck is used to drive the vacuum pump, so very large air flow is possible.
Uninterrupted fluid path.

DEBRIS TOLERANCE:
Can cope with soft and hard debris that will flow easily through the suction hose
(vacuum pump inlet must be protected.
Clogging when discharging from the vessel can also hamper operation

CHARACTERISTICS:
Maintenance: vacuum pump requires regular maintenance, as does the truck
Widely available in a variety of sizes, commonly 4-12 cubic meters
Can't suck directly up large elevations or over long distances
"Plug and chug" technique can be used to extend elevation or distance
(a small amount of fluid is sucked into the hose followed by a volume of air, and then repeated)
Uses a suction hose (3-4 inches, 75-100 mm diameter) that will fit most apertures

USE CASES:
Can be used to empty septic tanks and some pit latrines containing only modest
levels of debris that is small enough to flow through suction hose
Good road access near the vault is required

COMMERCIAL EXAMPLES:
Available almost everywhere, both new and used

ROM

Purchase price	$$$	Thin	Fast
Energy source	Engine	Medium-thin	Fast
Power	Medium	Medium	Slow
Energy efficiency	Medium	Medium-thick	No
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A 600-2,000 liter vacuum tank is mounted to a trailer with a vacuum pump powered by a petrol (gasoline) engine.

OPERATING THEORY: The ROM mimics the operating principles of a vacuum truck, in a miniature version.

DEBRIS TOLERANCE:

Can cope with soft and hard debris that will flow easily through the suction hose (vacuum pump inlet must be protected).

Clogging when discharging vessel can also hamper operation.

CHARACTERISTICS:

Maintenance: Vacuum pump and engine required regular maintenance

Can't suck directly up large elevations or over long distances

Weight: ~540 kg

3" suction hose will fit most apertures

USE CASES:

Hard to reach places, inaccessible by vacuum truck

Septic tanks and cesspits containing modest debris loading

COMMERCIAL EXAMPLES:

ROM VAC - Pick-Up units

WES Management (older version of ROM) – Blantyre, Malawi

Contact Harold Chirwa - harold.chirwa@gmail.com

PITVAQ (eVac)

Purchase price	$$$	Thin	Fast
Energy source	Electric or Petrol	Medium-thin	Fast
Power	Low	Medium	Fast
Energy efficiency	Medium	Medium-thick	Slow
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A small, portable vacuum system designed to be used in difficult to access areas.

OPERATING THEORY: The PITVAQ mimics the basic principles of a traditional vacuum truck. A 50-60 liter vessel is filled using a vacuum pump and then drained into small containers for transport.

DEBRIS TOLERANCE:

Generally can pass anything that can flow easily through hose. Offered with a screen

CHARACTERISTICS:

Maintenance: vacuum pump requires regular maintenance
Capable of producing vacuum equivalent to vacuum truck (~0.8 bar)
Standard vacuum hose can fit most latrine apertures (> 100mm)
Requires purchase of transport drums

USE CASES:

Designed specifically for use with pit latrines, including difficult-to-access facilities
Suction hose will fit in most small apertures
Approximately 20 units currently in use

COMMERCIAL EXAMPLES:

www.pitvaq.com
Partners in Development
(contact: Dave Still, dave@pid.co.za)
Pit Vidura – Kigali, Rwanda
(contact: Rachel Sklar, Rachel@pitvidura.com)

Minivac

Purchase price	$$$	Thin	Fast
Energy source	Engine	Medium-thin	Fast
Power	Low	Medium	Fast
Energy efficiency	Medium	Medium-thick	Slow
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A compact, portable vacuum system with a motor suitable for remote or congested areas.

OPERATING THEORY: The Minivac mimics the operating principles of a vacuum truck, in a miniature version. 3 product configurations exist and include the Minivac coupled with the (1) Drumit (2) Hopper and (3) Tank.

DEBRIS TOLERANCE: solids up to 2 inches (50mm) diameter

CHARACTERISTICS:

Maintenance: vacuum pump and engine require regular maintenance

Accessories:

(1) Drumit: 55 gallon drum filling vacuum head with automatic shut off valve

(2) Hopper: Tank that withstands Minivac's vacuum system and dumps sludge into collection drum beneath the hopper

(3) Tank: 110 gallon vacuum tank, offering easier mobility

Suction hose will fit most apertures

USE CASES:

Septic tanks and pit latrines containing only small debris. To the best of the author's knowledge, has not been deployed in fecal sludge operations.

COMMERCIAL EXAMPLES:

Elastec

1

2

3

PuPu Pump

Purchase price	$$$	Thin	Fast
Energy source	Electric	Medium-thin	Fast
Power	Low	Medium	Fast
Energy efficiency	Medium	Medium-thick	Slow
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A small, portable pneumatic pump system designed to be used in difficult to access areas.

OPERATING THEORY: The PuPu pump consists of a pneumatic pumping chamber that is filled via vacuum and discharged via compressed air. A portable compressor provides both vacuum and compressed air. Duckbill valves control the flow.

DEBRIS TOLERANCE:

Generally can pass anything less than 90mm and soft/flexible debris

CHARACTERISTICS:

Maintenance: Compressor requires regular maintenance

8m maximum lift and 20m maximum head

Standard vacuum hose can fit most latrine apertures (> 100mm)

Foam ball driven through hose with air pressure to clear hose

Safety concern due to compressed air

USE CASES:

Designed specifically for use with pit latrines, including difficult-to-access facilities

Suction hose will fit in most small apertures

COMMERCIAL EXAMPLES:

PRACTICA - Netherlands: factory production beginning in India in 2022, http://www.practica.org/wp-content/uploads/2021/06/Brochure-PuPu-pump.pdf (Contact: Robert Vuik, robert.vuik@practica.org)

SupaVac SV60, Solidsvac sv70

Purchase price	$$$$	Thin	Fast
Energy source	Compressed air (engine)	Medium-thin	Fast
Power	Extreme	Medium	Fast
Energy efficiency	Low	Medium-thick	Slow
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A pneumatic pumping system that cyclically fills and empties a pit-side vessel and can pump large distances. The pump vessel has no moving parts.

OPERATING THEORY: Vacuum is generated using a Venturi and used to fill the vessel. Once full, significant air pressure is used to evacuate the vessel out a discharge hose. Knife gate valves control the sludge flow.

DEBRIS TOLERANCE:

Can generally pass anything that will flow easily through the hoses

Debris can get stuck on knife gate valves and check valves

CHARACTERISTICS:

Requires compressor capable of delivering 300 CFM at 90 psi

Maintenance: Valve seals. Air compressor and engine require regular maintenance.

Standard suction hose can fit most latrine apertures

Requires training to use safely

Safety concern with the large amount of stored energy in the vessel when pressurized, which can lead to violent hose or vessel rupture

Very expensive to operate due to fuel consumption of air compressor

USE CASES:

Similar to vacuum truck but can pump greater distances and thicker sludge. To the best of the author's knowledge, has not been deployed in fecal sludge operations.

COMMERCIAL EXAMPLES:

SupaVac SV60, Solidsvac SV70,Compressor example

SupaVac SV60

Suitable Compressor

Mobile HoneyWagons

Purchase price	$$$-$$$$	Thin	Fast
Energy source	Human, electric, engine	Medium-thin	Fast
Power	Human - medium	Medium	Slow
Energy efficiency	High	Medium-thick	No
Flow rate	Medium - high	Thick	No

Definitions

OVERVIEW: A mobile pumping (manual or diaphragm) system ranging from 25-5,000 gallon storage tanks mounted on carts, ATV mounts or in trailer mounted configurations.

OPERATING THEORY: A "Mud Sucker" diaphragm pump is used to fill the vessel directly. Pumps use a swing-check or ball-check valve design to improve debris tolerance.

DEBRIS TOLERANCE:

- Small debris can be passed through the pump
- Large or stringy debris or clumps of thick sludge can prevent check valves from operating

CHARACTERISTICS:

- Self-priming
- Maintenance: Pump diaphragm will require periodic replacement. Engine requires regular maintenance
- Widely available in a variety of sizes, energy sources and mounting configurations
- Include a 3 way valve system, so waste can be pumped in and out of the tank
- Pumping capabilities range from 20, 80, 110 GPM with 1.5-2, 3, and 4 inch connections
- Can mount additional water storage tank on some models for fluidization

USE CASES: Septic tanks containing light debris loading. To the best of the author's knowledge, has not been deployed in fecal sludge operations.

COMMERCIAL EXAMPLES:

Wastecorp Pumps

Trailer/Pick-Up Truck Pumping Systems

Purchase price	$$$-$$$$	Thin	Fast
Energy source	Engine	Medium-thin	Fast
Power	Low - Medium	Medium	Slow
Energy efficiency	Medium	Medium-thick	No
Flow rate	Medium to high	Thick	No

Definitions

OVERVIEW: A pump with a water vessel attached to a trailer or to a frame for loading on a pick-up truck bed. Hoses convey the waste from the source to the vessel.

OPERATING THEORY: Engines attached to the system power the pumps (i.e. vacuum pump, trash pump) which remove waste from the pits. These smaller systems allow more mobility in space constrained regions where vacuum trucks cannot access.

DEBRIS TOLERANCE:

Depends on pump type. Vacuum pump systems will be similar to ROM, all others will struggle with significant debris loads

Clogging when discharging vessel can also hamper operation.

CHARACTERISTICS:

Maintenance: pump and engine require regular maintenance

USE CASES:

Hard to reach places, inaccessible by vacuum truck

Septic tanks and cesspits containing light to moderate debris loading

Uses a suction hose that can be inserted into most apertures

COMMERCIAL EXAMPLES:

Kam Avida (India): 1,000-8,000L tanks

Shri Balram Industries (India): 3,000-4,000L tanks

Clean and Green Equipments (India)

Flowbins (South Africa)

Transway Systems (Canada)

Grinder Pumps

Purchase price	$$$	Thin	Fast
Energy source	Electric	Medium-thin	Fast
Power	Low	Medium	Slow
Energy efficiency	Very high	Medium-thick	No
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A submersible centrifugal pump that includes a cutter on the inlet that chops soft materials into small enough pieces for the pump to ingest.

OPERATING THEORY: Cutting debris into small pieces allows small internal passages in the pump, which enables very high efficiency and high pressures.

DEBRIS TOLERANCE:

- Can cope with soft debris at a moderate loading
- Will reduce downstream debris issues.
- Hard debris will cause cutter wear or damage

CHARACTERISTICS:

- Maintenance: Cutter requires periodic sharpening or replacement
- Widely available in a variety of sizes and powers
- Capable of high flow and high pressure, so can pump long distances and uphill
- Not self-priming, so needs to be submerged
- Larger than most latrine apertures, so requires an access hatch

USE CASES:

- Are commonly built into septic tanks
- Could be lowered into a septic tank to empty it
- Care must be taken to prevent ingestion of debris that could damage the cutter (i.e. don't let it suck from the bottom of a tank that may have rocks in it)

COMMERCIAL EXAMPLES:

- Ashland Grinder Pumps
- Xylem Grinder Pumps

Trash Pumps

Purchase price	$$-$$$	Thin	Fast
Energy source	Electric, engine	Medium-thin	Fast
Power	Low	Medium	Slow
Energy efficiency	high	Medium-thick	No
Flow rate	Medium to high	Thick	No

Definitions

OVERVIEW: Also known as solids-handling pumps. A centrifugal pump capable of passing debris.

OPERATING THEORY: Large internal passages and an impeller designed to shed debris allow passage of some types and sizes of trash.

DEBRIS TOLERANCE:

Can pass debris below its rated solids size

Large or stringy debris can cause clogs

CHARACTERISTICS:

Maintenance: seals require periodic replacement. Engine requires regular maintenance

Widely available in a variety of sizes and powers

Capable of high flow but not high pressure

Most are self-priming

Uses a suction hose that can be inserted into most apertures

USE CASES:

Can be used to empty septic tanks containing only small debris where the discharge distance and elevation is minimal

COMMERCIAL EXAMPLES:

Powerhorse DS30W

Gorman Rupp 13C3-E3 3P

Progressive Cavity Pumps

Purchase price	$$$	Thin	Fast
Energy source	Electric	Medium-thin	Fast
Power	Low	Medium	Fast
Energy efficiency	Medium	Medium-thick	Slow
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A positive displacement pump often used in industry to pump sludges.

OPERATING THEORY: A long rotor rotates eccentrically within an elastomeric stator, forming a "cavity" that moves from inlet to outlet.

DEBRIS TOLERANCE:

Can pass debris below its rated solids size, which is usually small

Long or stringy debris can easily wrap around the rotor and jam the mechanism

CHARACTERISTICS:

Maintenance: stator requires periodic replacement

Widely available in a variety of sizes and powers

Capable of medium flow and high pressure

Most are self-priming

Uses a suction hose that can be inserted into most apertures

USE CASES:

Can be used to empty septic tanks and pit latrines, except for those with very thick sludge. Large debris loading can cause clogs and debris that can wrap around the rotor can cause jams. To the best of the author's knowledge, it has not been deployed in fecal sludge operations and is not recommended without further study.

COMMERCIAL EXAMPLES:

Netzsche Progressive Cavity Pumps

Seepex Progressive Cavity Pumps

Flexible Impeller Pumps

Purchase price	$$$	Thin	Fast
Energy source	Electric	Medium-thin	Fast
Power	Low	Medium	Medium
Energy efficiency	Low	Medium-thick	No
Flow rate	Medium	Thick	No

Definitions

OVERVIEW: A positive displacement pump often used in industry to pump clean liquids and sludges.

OPERATING THEORY: A flexible rotor rotates within a stator that causes the rotor vanes to flex and create a variable volume that moves from inlet to outlet.

DEBRIS TOLERANCE:

Can pass debris below its rated solids size

Long or stringy debris can easily wrap around the rotor and jam the mechanism

CHARACTERISTICS:

Maintenance: Rotor requires periodic replacement

Limited selection of suppliers and models

Capable of medium flow and medium pressure

self-priming

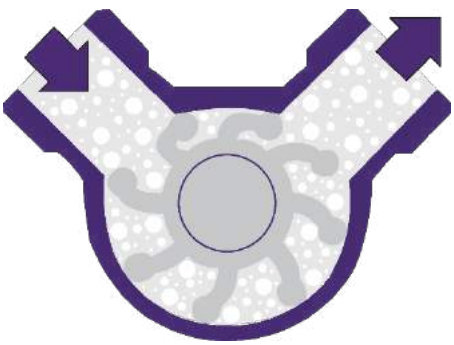
Uses a suction hose that can be inserted into most apertures

USE CASES:

Can be used to empty septic tanks and pit latrines with thinner sludges. Capable of passing fairly large debris, but it can wrap around the impeller and cause impeller damage. To the best of the author's knowledge, it has not been deployed in fecal sludge operations and is not recommended without further study.

COMMERCIAL EXAMPLES:

Xylem Veraflex



Gulper

Purchase price	$	Thin	Fast
Energy source	Human	Medium-thin	Fast
Power	Human	Medium	Slow
Energy efficiency	High	Medium-thick	No
Flow rate	Low	Thick	No

Definitions

OVERVIEW: A manually operated pump for emptying wet pit latrines. It's constructed from stainless steel for the puller rod and the valves, and standard PVC pipes and fittings for the main body.

OPERATING THEORY: The device is based on a simple direct action type hand pump – a butterfly type valve is fitted on the bottom of the puller rod and another is fitted in the bottom of the riser pipe as a 'check-valve'. The pump is operated by either one or two pit emptying operators. The handle is raised and lowered which lifts the contents of the pit up through the riser pipe. This is then discharged through the angle 'T' outlet pipe at the top of the Gulper.

DEBRIS TOLERANCE:

- Can pass small debris
- Large or stringy debris will prevent butterfly valve operation and cause clogs

CHARACTERISTICS:

- Can be fabricated locally
- Manual pumping rate of approximately 30 L/min
- 2m long and 100mm diameter riser pipe

USE CASES:

- Pits less than 1.5m deep
- Liquid sludge with low solid waste content

COMMERCIAL EXAMPLES:

- WaterAid Tanzania
- IP and design is open source
- Open Source Designs

Standard Manual Methods

Purchase price	$	Thin	Fast
Energy source	Human	Medium-thin	Fast
Power	Human	Medium	Fast
Energy efficiency	High	Medium-thick	Slow
Flow rate	Low	Thick	Slow

Definitions

OVERVIEW: Locally available hand tools including buckets, ropes, rakes and long handled shovels/scoops are used to manually remove sludge from pits.

OPERATING THEORY: Useful for difficult pits with high levels of trash, thick sludge, low ability to pay, or road inaccessibility.. This practice is illegal in many countries, while other regions are working to formalize manual emptying services.

DEBRIS TOLERANCE:

All types are debris are manageable

CHARACTERISTICS:

Maintenance: Frequent vaccination/deworming of employees

Hand tools are readily available locally, but will require frequent replacement

Time intensive process (empty 1-2 pits per day)

Can access the most difficult-to-reach pits

Major employee education, vaccination, PPE, and health and safety training is required

USE CASES:

Pits inaccessible to mechanized means of emptying

Servicing customers with low ability to pay

COMMERCIAL EXAMPLES:

eThekwini Metropolitan Municipality, South Africa

Pan-African Association of Autonomous Sanitation Actors (APAA)

Sludge Digger

Purchase price	$	Thin	No
Energy source	Human	Medium-thin	No
Power	Human	Medium	Fast
Energy efficiency	High	Medium-thick	Fast
Flow rate	Low	Thick	Slow

Definitions

OVERVIEW: A manual tool for thick sludge laden with trash, the scoop is mounted on a pivot and is connected to a rope to allow the scoop to be pulled up to extract sludge.

OPERATING THEORY: Force can be applied on this scoop, allowing it to go through thick sludge. It can also scoop out trash without fear of clogging pumps or requiring user behavior change regarding solid waste.

DEBRIS TOLERANCE:

Can tolerate debris up to the size of the scoop

CHARACTERISTICS:

Maintenance: Rope replacement

Can easily be locally manufactured (4.3 kg)

Can access the most difficult-to-reach sanitation facilities

Fits within most pit latrine apertures

Easiest to use from a vertical access point

Long handled to allow access to deep pits

USE CASES:

Extremely thick or trash laden pits

Pits inaccessible to mechanized methods of emptying

COMMERCIAL EXAMPLES:

Manual for local manufacture is available
from Dale Andreatta, Ph.D., P.E.
dandreatta@sealimited.com

The Claw (Trash Removal)

Purchase price	$	Thin	NA
Energy source	Human	Medium-thin	NA
Power	Human	Medium	NA
Energy efficiency	High	Medium-thick	NA
Flow rate	NA	Thick	NA

Definitions

OVERVIEW:
The Claw is a manual tool that has four flexible steel arms that can be retracted into the handle to grab trash of any size or shape and discard into a rubbish bin without the user coming in contact with the waste or sludge. Typically the entire claw is 1.5 – 2m long.

OPERATING THEORY:
When the handle is pushed down, the claw opens. To retrieve the trash, the handle is pulled up which tightly closes the claw around most any type of trash (bags, clothes, bottles).

CHARACTERISTICS:

- Approximately 1.5 - 2 meters long
- No catch points
- No contact with sludge or trash
- Fits within most latrine apertures

USE CASES:

- Works best with thinner sludge and with trash that can be visually spotted by the users
- Very good at retrieving bottles

COMMERCIAL EXAMPLES:

- Pit Vidura

Hook (Trash Removal)

Purchase price	$	Thin	NA
Energy source	Human	Medium-thin	NA
Power	Human	Medium	NA
Energy efficiency	High	Medium-thick	NA
Flow rate	NA	Thick	NA

Definitions

OVERVIEW:
Different versions of manually operated hooks are used for trash removal ("fishing") prior to emptying with vacuum or pumping systems.

OPERATING THEORY:
Hooks typically consist of multiple small, metal rods welded onto one primary metal pole. The operator manually moves the hooks around the pit sludge, catching debris such as clothes, sanitary products, hair, etc. The debris is then manually removed by the operator and placed in bins for transport.

CHARACTERISTICS:

- Approximately 1.5 - 2 meters long
- Doesn't require direct visibility to capture trash
- Requires direct contact with sludge/debris
- Fits within most latrine apertures

USE CASES:

- Good at capturing most debris, even in thick sludge
- Poor at removing rigid debris, such as plastic or glass bottles

COMMERCIAL EXAMPLES:

- WES Management– Blantyre, Malawi, contact Harold Chirwa, harold.chirwa@gmail.com

Case Study – Kigali, Rwanda

OPERATOR: Pit Vidura (www.pitvidura.com)
Rachel Sklar (rachel@pitvidura.com)
Nicholas Kuria (nicholas@pitvidura.com)

REGIONAL OVERVIEW: Kigali is located in an area of rolling hills and contains both planned settlements, containing mostly corporate customers, and informal settlements, containing mostly household customers.

Customers in planned settlements can be accessed by large trucks. Some customers in informal settlements can be reached by small trucks, but others cannot be accessed by a vehicle.

Customers comprise approximately 50% pit latrines, 40% septic tanks, and 10% pit latrines with soak pits (low-tech leach field for effluent).

The sludge encountered in septic tanks is usually thin, while pit latrines vary between thin and thick. Pit latrines contain an average of 300 liters of trash.

The sludge is transported to a dumpsite 18 km from the city center.

Willingness to pay for emptying (1,200 liters) varies from 15% at $70 to 100% at $24.

PIT VIDURA'S SOLUTIONS:

A large vacuum truck it used whenever it can access a site (clean, fast, fewest trips to dump site).

A small vacuum truck is used if it can access a site but a large truck cannot (clean, fast).

Most other sites can be services by Pit Vidura's "DoVac" system:

- An eVac is used at the pit to suck sludge into a container.
- A vacuum truck is used at the road to suck sludge from the container.
- By removing the burden of lifting sludge out of the pit (many of which are very deep in Kigali), the vacuum truck can suck over a greater distance.

For the most difficult to access pits, an eVac is used to fill barrels which are carried to a flat-bed truck.

Vacuum trucks are able to service 3-4 pits per day. The "DoVac" and barrel systems can service 2 pits per day.

The more mechanized the process, the faster, cleaner, and more profitable it is, though with more upfront cost. The more manual the process, the more pits can be accessed with less upfront cost, though it is slower, dirtier, and less profitable.

Trash is dealt with by manually fishing and is a major impediment to profitability.

Case Study – Dar es Salaam, Tanzania

OPERATOR: BORDA (www.borda-africa.org)
Tim Fettback (fettback@borda-africa.or.tz)
Charles Muhamba (muhamba@borda-africa.or.tz)
Methusela Bahame (bahame@borda-africa.or.tz)

REGIONAL OVERVIEW: Dar es Salaam is located in a mostly flat area with small river valleys that are prone to flooding. BORDA initiated a decentralized service with a focus on informal settlements, which is operated by the Dar es Salaam Water Supply and Sanitation Authority (DAWASA) since 2020.

Access to pits varies, with some accessible by large truck and some not accessible by vehicle at all.

Customers comprise a mix of septic tanks and pit latrines.

Most of the sludge is thin, but often contains significant trash.

Based on data from the start-up period, the sludge is transported (round trip) 3-5 km by motorized tricycle or 15-20 km by vacuum truck to a decentralized FSTP.

For 3 m^3 (vacuum truck) of sludge removal, private emptiers charge $25-43, DAWASA charges $22. Additionally, DAWASA offers the 1m^3 service by motorized tricycle for US $6.5. Many pit owners will use illegal informal emptiers at a lower cost.

BORDA'S SOLUTIONS:

A small vacuum truck it used whenever it can access a site (clean, fast, fewest trips to treatment site).

Otherwise, a motorized tricycle and barrels are used in conjunction with:

- eVac with electrical engine (low OpEx, handles thicker sludges and some trash, very mobile).
- Trash pump (very fast, low OpEx, very mobile, somewhat expensive, can only pump thin sludge).
- Gulper (low cost, low OpEx, only used when nothing else can access pit).
- Basic water/mud pump (low cost, very mobile, can only pump thin sludge, frequent maintenance and replacement).

Based on the data from the start-up period Vacuum trucks service 3 pits per day (sometimes more). The tricycle-based systems service 2 pits per day. The number of services can be increased when the demand is higher, and the time waiting for customers is minimized.

Case Study – Dar es Salaam, Tanzania

REJECTED SOLUTIONS:

Small vacuum trailer similar to ROM (too expensive to fabricate locally).
Electric eVac (grid power too unreliable).

Case Study – Blantyre, Malawi

OPERATOR: WES Management (wesmalawi.wordpress.com)
Harold M. Chirwa (harold.chirwa@gmail.com)

REGIONAL OVERVIEW:

Blantyre city lies in a hilly region of varied topography.

Customers include private homes and institutions.

Low- and high-income areas are serviced. High income customers typically use septic tanks; sludge is thin and easy to remove. Low-income customers use lined pit latrines; sludge is thick and usually contains high volumes of trash (between 500-1,000 L per pit).

Pit access varies, with some pits in hard-to-reach areas and others easily accessible by road.

Most pits are accessed for emptying via the aperture (squat plate/squat hole with a 3-inch diameter).

Limited disposal sites are available, so transport distances vary.

Prices vary customer to customer. The customer segmentation goes together with the pricing segmentation using the 80/20 Pareto principle, with low-income customers offered a lower rate. 80% of customers are low-income and provide 20% of the revenue, while 20% of high-income customers provide 80% of company revenue. Some customers expect the service free of charge.

On a good day, one team can empty 8 to 12 pits per day.

WES MANAGEMENT'S SOLUTIONS:

Trash is removed from pits manually using a fishing tool. This process is slow.

25-30L of water per m^3 of sludge is required for fluidization of thick sludge pits.

The Mobile Desludging Unit ROM is the technology of choice for accessible sites (made for hard sludge and difficult to reach areas, however the low containment volume (1,000L) and distance to the disposal areas proves challenging).

The Gulper is used as a last option and is usually used for very hard to reach areas. Hard to reach areas include areas accessed only by footpaths, areas where the access point involves crossing a stream, and areas of high and low elevation where vehicles, including motorcycles, cannot reach.

REJECTED SOLUTIONS:

Diaphragm Pump (the thick sludge, which made priming difficult, and high trash volumes continuously blocked the pumping system, making emptying services too time intensive).

Vacutag (transport is very slow (4 km/hr), it cannot handle rough terrain or mild slopes, is unstable, and difficult and dangerous to tow. Several mechanical issues observed (including challenges with the diesel engine and melting suction pipes) led to abandoning the technology).

Vacuum Truck (low mobility and accessibility, could not pump thick sludge with high trash volumes, low-income areas proved very challenging, only suitable for septic tanks).

Case Study – Bangladesh

OPERATOR: Practical Action (https://practicalaction.org/)

Uttam Saha (uttam.saha@practicalaction.org.bd)

REGIONAL OVERVIEW: Emptying services are offered in 10 secondary cities, all relatively flat, with variable access to skilled labor and supply chains.

Customers comprise a mix of septic tanks and pit latrines, with latrines more prevalent in low-income or rural areas. Pour flushing is common.

Most customers are shared household facilities; other customers include commercial and institutional entities. Single household families are unlikely to put trash in toilets, however, other customer types often mix trash and sludge, making emptying difficult.

The municipality and informal service providers offer emptying services, charging customers based off factors including volume of sludge, sludge thickness, equipment accessibility to the facility and number of trips required. Fees range from $35-$60.

Access to pits vary, with some accessible by large truck and some not accessible by vehicle at all.

Emptying teams typically empty between 2-4 facilities per day (max 10/d). Septic tanks are faster to empty than pits.

Practical Action learned lots of emptying technologies are labor intensive, esp. for transporting sludge. They recommend keeping technologies simple and low cost.

A combination of emptying technologies and transport vehicles were used for a citywide inclusive sanitation approach. More advanced cities preferred using more advanced technologies. Transport vehicles were determined by facility accessibility.

PRACTICAL ACTION'S SOLUTIONS:

Emptying Technologies

Manual ($95) and Mechanical Gulper ($590) (Low OpEx, local availability, 1 operator, low-skilled labor, highly labor intensive).

Submersible Pump ($590) (Efficient esp. for solids portion of sludge, able to discharge sludge over longer distances, 3 operators, High OpEx, spares not locally available, skilled operator required).

Hi-Cap Super Sucker Pump (Diesel engine operated $560 or electric motor operated $470) (Locally manufactured, low OpEx, low-skilled operator, 2 operators, good for removing semi-solids portion, noisy).

Case Study – Bangladesh

Transport Technologies

Tuk-Tuk (piki-piki) with 1,200L sludge holding tank (locally manufactured, $3.5k).

Small truck with 1,500L sludge holding tank (locally manufactured, $7k).

Tractor trailer with 2,000L sludge holding tank (locally manufactured, $9.4k).

Sludge transporter (BRAC) with 2,000L sludge holding tank (locally manufactured, high CapEx $23.4k, limited access in low-income areas).

Imported Chinese Vacutug: 2,000L (hard to source local spare parts/maintenance, limited accessibility in low-income areas, high CapEx $35k).

Techniques

If the sludge is too thick to be pumped effectively, fluidization can be employed:

- Thicker sludges can be made more pumpable by adding water and/or agitating. It increases the total volume to be emptied, but allows more options for pumping.
- The simplest method is to use buckets to add water and agitate with a paddle, pole, or shovel.
- If a pressurized water source is available, a jet of water can be used to fluidize sludge at the inlet as it is sucked up.
- A pressure washer can be used to more quickly fluidize and potentially use less water.

If there is too much trash for effective pumping, fishing can be employed:

- Manually removing trash prior to emptying can allow more pumping options and faster emptying.
- Various tools are used, ranging from simple hooks to more bespoke tools.
- Care must be taken to prevent unsanitary conditions.

If a pit is highly stratified, homogenization can be employed.:

- Many pits are stratified with a thick sludge layer at the bottom, a liquidy layer in the middle, and a floating scum layer on top.
- By mixing all three layers together, a single system may be able to empty the entire vault.
- Mixing can be mechanical with a paddle, or by pumping liquid from the middle layer and jetting it back into the thick layers.

If a vacuum truck (or similar technology) is being used but it is struggling due to thick sludge, a long distance, or a large elevation gain, plug and chug can be employed:

- First, a small amount of sludge is sucked up (a plug).
- Then, the suction hose is lifted out of the sludge and a large volume of air is ingested (chug).
- The process is repeated as long as necessary.
- The large volume of air will “entrain” sludge along the length of the hose and may be more effective than completing filling the hose with sludge.

Technology Currently Under Development

CRABTRAP: A manual fishing device for removing trash from pits. The design is effective at removing bottles and similar types of trash which are difficult to grab with a hook.

Status: In Development, Ohio State University

https://forum.susana.org/99-faecal-sludge-transport-including-emptying-of-pits-and-septic-tanks/21446-clearing-trash-from-pit-latrines-a-new-device

Contact for designs: Dale Andreatta, Ph.D., P.E. dandreatta@sealimited.com

DOUBLE LUNG PUMP: Two elastomeric lungs inside rigid chambers are alternately filled and emptied by the transfer of water into and out of the chambers. Two check valves per lung direct the flow.

Status: Currently under development

https://www.ideeeprodotti.it/

EMAS MANUAL SLUDGE PUMP: A manually powered sludge pump which allows some solid waste to pass through the pump, and is capable of pumping medium sludge.

Status: Research and Development, EMAS International

https://www.globalinnovationexchange.org/innovation/manual-sludge-pump

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

EXCLUDER: A dynamic pump screen which rejects trash at the inlet pipe and uses an augur to help remove thick sludge from pits.

Status: Commercialization and field-testing in Ghana, North Carolina State University

https://www.excluder.org

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

http://www.susana.org/_resources/documents/default/2-1712-wrc-1745-tackling-the-challenges-of-full-pit-latrines--volume-3.pdf

Technology Currently Under Development

JALODBUST SLUDGE REMOVER: A portable, battery-powered, sanitary sludge handling device designed to work as a sewage pump, agitator and de-clogger.

Status: In validation phase, needs funding for semi-industrial design and commercialization

https://www.engineeringforchange.org/solutions/product/jalodbust-sludge-remover/

https://www.startupindia.gov.in/content/dam/invest-india/Templates/public/covid_resource_section/listicles/Covid%20Startup%20Solutions_LARGE%20AREA%20SANITIZATION%20AND%20STERILIZATION.pdf

SHITMASTER: A trash pump with a collection tank on a 3 wheeled motor vehicle for accessing tight passageways.

Status: Implemented by Sama Sama in Ghana, but not commercially available. Sama Sama is upgrading the system currently.

https://washmarkets.ideglobal.org/country-learning/how-many-products

Previously Developed Technologies

BANGALORE SCREWER: A technology which uses an auger to lift sludge from a pit, which is operated with a hand crank.

Status: was not developed beyond early prototyping phase

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

http://www.susana.org/_resources/documents/default/2-1712-wrc-1745-tackling-the-challenges-of-full-pit-latrines--volume-3.pdf

FECAL SLUDGE OMNI INGESTOR – AGI: A wheeled vacuum container incorporating a vacuum pump at the top to suck up sludge and a progressive cavity pump at the bottom to pump the sludge to the road. Both pumps are hydraulically powered with a power pack at the road.

Status: Was not developed beyond early prototyping phase

http://www.agieng.com/

FECAL SLUDGE OMNI INGESTOR – DCI: A SupaVac mounted directly to a vacuum truck and discharging directly into the tank.

Status: was not developed beyond early prototyping phase

FECAL SLUDGE OMNI INGESTOR – SYNAPSE: A cart-mounted vacuum container consisting of two chambers. The lower chamber houses a centrifugal separator to separate large and heavy debris. The upper chamber contains a grinder pump to pump sludge to the road. A small vacuum pump primes the system and maintains the fluid level.

Status: was not developed beyond early prototyping phase

www.synapse.com

Contact: Tom Gurski (tom@carbyne-enterprises.com)

GOBBLER: A more robust version of the Nibbler, the Gobbler uses a chain and scoops within a pipe to remove sludge from pits.

Status: Research and Development stopped due to challenges observed during testing.

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

http://www.susana.org/_resources/documents/default/2-1712-wrc-1745-tackling-the-challenges-of-full-pit-latrines--volume-3.pdf

Previously Developed Technologies

KEDOTANG: A pump and small collection tank on a 3-wheeled sludge cart for mechanized emptying in narrow spaces.

Status: Not commercialized, implemented by RW Siaga++ in Indonesia

https://www.csmonitor.com/World/Making-a-difference/Change-Agent/2012/0619/Three-wheeled-carts-better-septic-tanks-help-clean-up-Jakarta

Reference: Tilley, E. Ulrich, L. Luethi, C. Reymond, P. Zurbruegg, C. (2014): Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag)

MANUAL SLUDGE PUMP FROM BEAUMONT DESIGNS: A manually operated pump for Medium-Thin sludge which requires 2 operators.

Status: Needs funding for further Research and Development.

https://forum.susana.org/forum/categories/99-faecal-sludge-transport-including-emptying-of-pits-and-septic-tanks/16618-solicitation-for-manual-pump-testing-partners

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

MAPET: A human-powered vacuum system consisting of two components, a piston pump and a 200 liter vacuum tank, both mounted on push carts.

Status: Research and Development stopped due to challenges observed during testing.

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

http://www.susana.org/_resources/documents/default/2-1712-wrc-1745-tackling-the-challenges-of-full-pit-latrines--volume-3.pdf

MAQUNIETA MAPUTO: A 1.5m3 transfer tank pulled by a 2-wheel tractor, either to accompany Vacutug to help transfer sludge long distances to treatment stations or service pit latrines directly with a small suction pump (the tank could also be used as a mini transfer station)

Status: Not commercialized, implemented by Medicins Sans Frontieres in parallel with Vacutug

Reference: O'Riordan, Mark. "Investigation into methods of pit latrine emptying." *Partners in Development, WRC Project* 1745 (2009).

Previously Developed Technologies

NANOVAC: A vacuum technology powered by 2 piston pumps (built off learnings from the MAPET), used for sucking and blowing air for sludge removal out of the pits and for removing sludge from the collection tank.

Status: Tested prototype was not robust enough for field testing.

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

PIT SCREW AUGER: A fully-mechanized auger which uses a screw within a pipe to lift sludge out of the pit.

Status: Needs funding for further Research and Development.

VACUTUG: A 0.5 m3 steel vacuum tank connected to a sliding vane vacuum pump.

Status: Research and Development stopped due to challenges observed during testing.

Still in use by Practical Action, Bangladesh. May be manufactured by ASL in China.

https://wedc-knowledge.lboro.ac.uk/resources/pubs/Desk_Study_of_MPE_Technologies_GOAL_Sierra_Leone.pdf

http://www.susana.org/_resources/documents/default/2-1712-wrc-1745-tackling-the-challenges-of-full-pit-latrines--volume-3.pdf

Definitions

APERTURE: The opening of a vault through which waste enters, such as the squat hole of a pit latrine, or the hole connected to the s-bend of a pour-flush toilet.

CENTRIFUGAL PUMP: A dynamic pump that uses a spinning impeller to increase the pressure of a fluid.

ENERGY EFFICIENCY: How much of the supplied energy is converted into fluid energy for pumping versus how much is wasted. Directly affects operating expense.

ENERGY SOURCE:

- **Human:** only requires manual labor, no alternative energy source
- **Household:** can be operated from a typical household outlet or small generator
- **Dedicated:** requires a standalone power supply
- **Electrical:** Requires electricity
- **Engine:** Energy is supplied by an internal combustion engine
- **Compressed air:** Energy is supplied by an air compressor, which is usually driven by an engine

FISHING: Using manual tools to remove trash from pit sludge, often a second step (following fluidization) before removal of trash-laden sludge is possible by mechanical means.

FLOW RATE:

- **Low:** Less than 60 liters per minute
- **Medium:** 60-250 liters per minute
- **High:** More than 250 liters per minute

FLUIDIZATION: The process of adding water to and agitating thick sludge to make it thinner and easier to pump, vacuum, or handle.

HOMOGENIZATION: The process of mixing stratified sludge to create sludge of more uniform thickness.

METHODS FOR EMPTYING PIT LATRINES

- **Manual:** human powered, with the aid of hand tools (ex. buckets, shovels, ropes)
- **Semi-Mechanized:** a combination of using a machine and human power (ex. PitVaq, PuPu Puump)
- **Mechanized:** full service by use of a machine (ex. vacuum truck)

Definitions

PLUG AND CHUG: A technique when using a vacuum truck whereby a relatively small amount of sludge is sucked up followed by a large volume of air and then repeated

POWER:

- **Human:** Powered provided by a person (<200 Watts)
- **Low:** <5 kW
- **Medium:** 5-20 kW
- **High:** 20-50 kW
- **Extreme:** >50 kW

PPE: Personal protective equipment, often including close-toed shoes, overalls, goggles, gloves, and facemasks.

PURCHASE PRICE SCALE:

- $ tens of dollars
- $$ hundreds of dollars
- $$$ thousands of dollars
- $$$$ tens of thousands of dollars

SELF-PRIMING: The ability of a pump to start dry and suck fluid uphill until it is completely full of fluid and pumping normally

SEPTIC TANK: A tank used to hold liquid from one or more waste sources, such as a flush toilet, pour-flush toilet, or shower. Some are configured to cause solids to settle in one part of the tank and for relatively clean effluent to be discharged from another part of the tank into a leach field.

SLUDGE THICKNESS:

- **Thin:** watery
- **Medium-thin:** liquid, but with noticeable viscosity (syrup/honey)
- **Medium:** Semi-solid, but will flow under gravity (porridge)
- **Medium-thick:** won't flow under gravity, but is easily manipulated (healthy human feces)
- **Thick:** Requires noticeable force to manipulate (dough or clay)

STRATIFICATION: The separation of sludge in a vault into distinct layers. Often a thick, dense sludge layer will be on the bottom, a liquid layer in the middle, and a thick, floating scum layer on top.

SUBMERSIBLE PUMP: A pump with a sealed motor and drive that is designed to be submerged in a fluid and to ingest fluid directly from its surroundings.

Definitions

VAULT: An enclosed space for the containment of waste. Examples include lined pits, unlined pits, partially lined pits, simple tanks, and multi-chamber tanks.

VENTURI: A fluid device that creates suction by accelerating a flow of air through a narrow passage.

A Practical Guide to Available Pit-Emptying Technologies

Published by the FSM Alliance
Digital versions of this publication can be found at www.fsm-alliance.org