German humanitarian assistance
Deutsche Humanitäre Hilfe

WASH in Emergencies 2015

WASH NETZWERK

Compendium of Faecal Sludge Management (FSM) Technical Options in Emergencies

German Toilet Organization
BORDA
arche noVa Initiative für Menschen in Not

Note: Fishing for solid waste and fluidising thick sludge can also be performed to facilitate emptying

* indicates options that are still under development

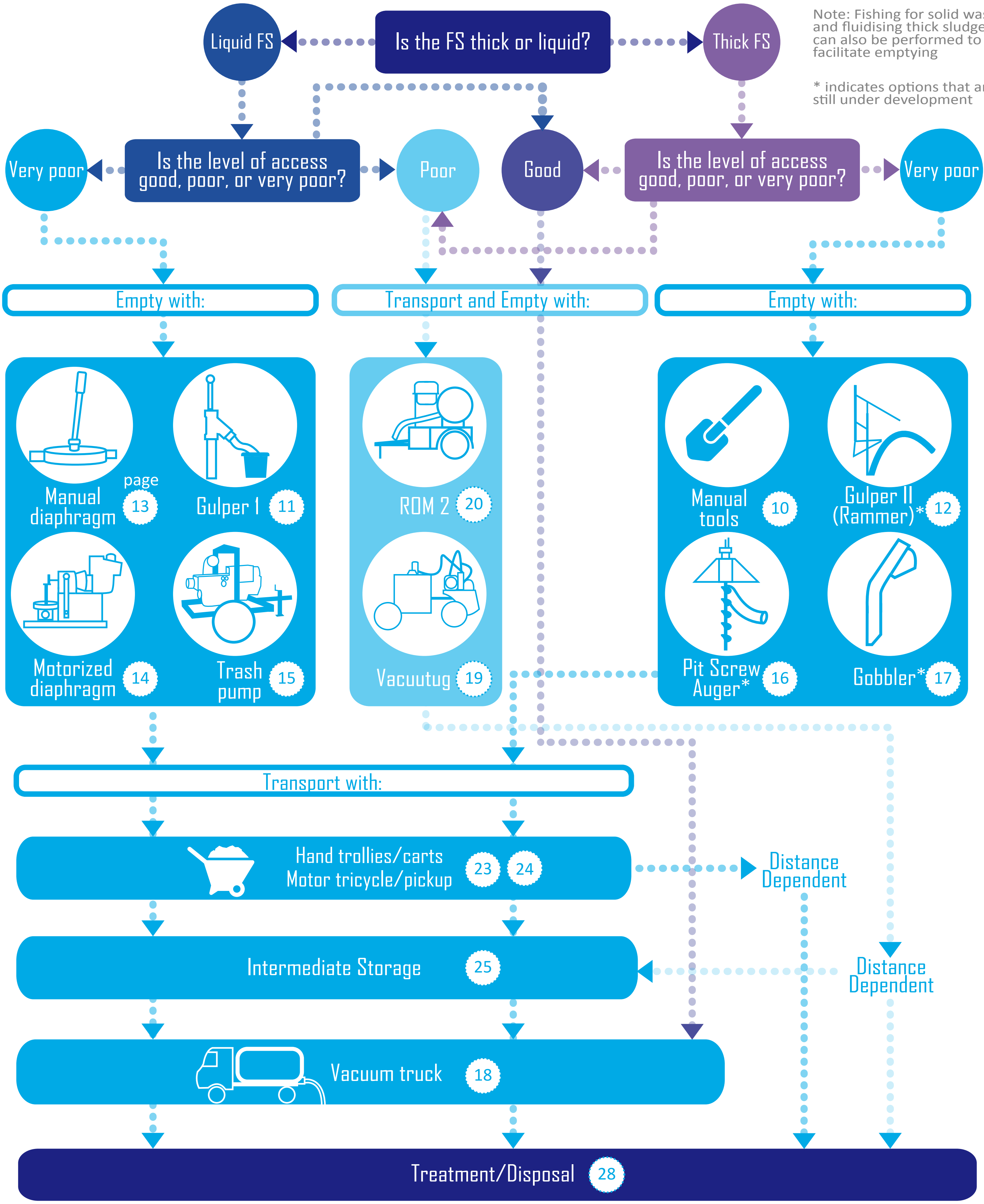


Table of Contents

Introduction

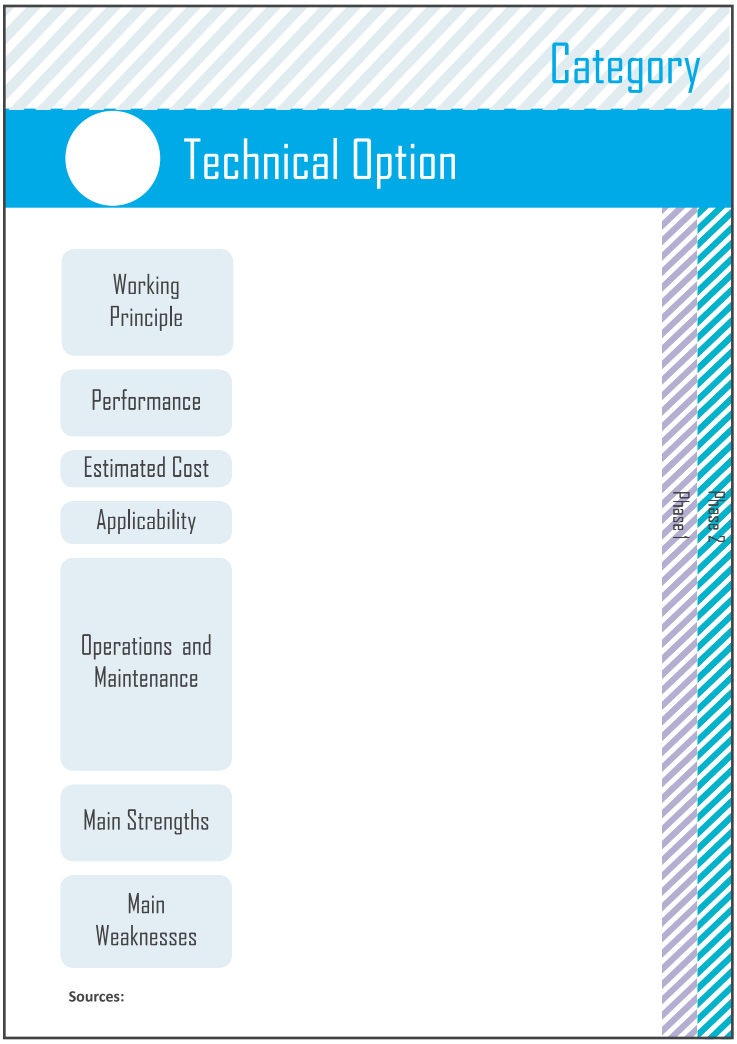
Purpose and Use of the Compendium

This compendium presents a range of technical options relating for collection, transport, treatment and disposal of fecal sludge in an emergency . It should be used as a guide to identify possible solutions for specific emergency situations and contexts. The final choice of options may need to combine different approaches and technologies and will depend on the phase of the emergency.

Each technology option is presented according to its working principle, performance, estimated cost, applicability, operation and maintenance requirements and its main strengths and weaknesses.

Navigating the Compendium

Those options that are suited to the first or second phases of an emergency are indicated in the compendium by the labels on the right side of each page, purple indicating phase 1 and teal indicating phase 2.



Phase 1

In this phase, mortality rates can be high and there may be a risk of a major epidemic. This phase can last up to several months. The main objective for an FSM programme is to minimize contamination related to high-risk practices and reduce exposure and faecal-oral disease transmission. Interventions are usually rapid and designed for the short term.

Phase 2

The 2nd phase more sustainable interventions can be implemented for longer-term use. Typically, community structures are reestablished and mortality rates start to fall. However, the risk of epidemics may still be high. This phase can last from several months to many years, depending on the complexity of the emergency.

Guiding Principles

The following principles should be applied when collecting, transporting, storing and treating/disposing of FS:

- Subject to local regulations, FS collection, treatment and disposal systems should not pollute clean surface water sources, be at least 30 meters from any surface water source and the bottom of any FS pit be at least 1.5 meters above the groundwater table. (This does not apply to saline groundwater (>1,500µS/cm^2))
- FS is transported in a leak proof container that is only emptied at an authorized location
- Treatment and/or final disposal sites prevent the exposure of the general population to public health risks
- Transfer operations should not result in the spillage of FS
- Workers involved in the emptying, transport, treatment or disposal of FS are provided with protective gear and follow protocols to protect their health and safety

Sources:

Reed, B. (2010). Emergency Excreta Disposal Standards and Options for Haiti. Retrieved 08 25, 2015, from Water, Engineering and Development Centre (WEDC): http://wedc.lboro.ac.uk/resources/pubs/Emergency_EDS_and_options_for_Haiti.pdf

Peepoo Bags

Working Principle

- A single use biodegradable bag with urea, with an inner layerthat unfolds to form a wide funnel to receive urine and faeces
- When the urea comes into contact with faeces or urine it inactivates the harmful pathogens
- The bag and its contents break down into carbon dioxide, water and biomass and can be used as a fertilizer

Performance

- Can be used anywhere
- Once it is closed, remains odor-free for at least 24 hours after use
- Can be used as fertilizer 2 to 4 weeks after use
- Has a guaranteed shelf life of two years

Estimated Cost

- Low cost

Applicability

- Areas where there is no toilet access, flooded areas, areas with a high water table and other locations where toilets are unsuitable

Operations and Maintenance

- Distribution of bags can be carried out through local micro-entrepreneur sales men/women or Peepoo NGOs and Partners
- Users will need some guidance on how to use Peepoo bags
- The bags can be placed over a small pot or bucket to facilitate use
- Once used, the individual bags can be collected in larger bags or other containers prior to composting

Main Strengths

- Low cost
- No water required
- Easy to use and carry
- Can be used anywhere
- Requires little space
- No investment in infrastructure
- Safe and secure

Main Weaknesses

- A robust logistical system is required to distribute, collect and process the bags and to enable Peepoo to be used as a fertilizer
- A large number of Peepoo bags stored in an open vessel, can produce a strong odor
- If bags are not used or disposed of properly it could lead to human contact with faeces and environmental contamination

Sources:
Start Thinking PeePoople. Retrieved 08 05, 2015, from: http://www.peepoople.com/peepoo/start-thinking-peepoo/
Wirseen C. (n.d.). Thinking like a business: Experience from urban Kenya. Retrieved 08 05, 2015, from: www.sanitationmarketing.com/LiteratureRetrieve.aspx-?ID=161784
Gur, E. (n.d). Sustainable Sanitation and Water Management: The Peepoo. Retrieved 08 05, 2015, from: http://www.sswm.info/content/peepoo

Trench Latrine

Working Principle

- Long trench excavated to at least 20-30 cm wide and 15 cm deep with up to 6 cubicles sited on top
- For deeper trenches, at least the top 50 cm of the pit should be lined to prevent collapse
- Wooden, concrete or plastic toilet slabs are placed on the trench
- Users cover their faeces with soil using a shovel

Performance

- 0.25 m^2 of land is required per person per day

Estimated Cost

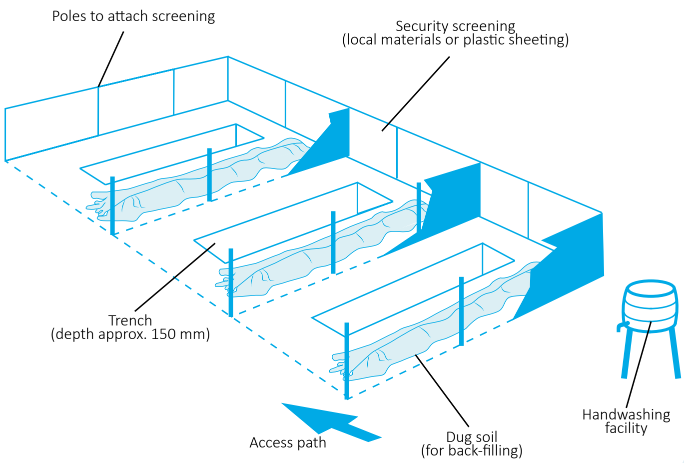
- Low cost

Applicability

- Feasible short-term emergency solution where enough space is available

Operations and Maintenance

- When a section of trench has its bottom layer fully covered with excreta, it is covered with soil and compacted
- A short length of trench should be used and closed before opening another section for use in order to ensure effective use of the trench space
- Separate facilities are required for men and women



Main Strengths

- Quick to install, one worker can dig 50m of trench per day
- Does not require water for operation
- Is easily understood by workers and users

Main Weaknesses

- Privacy is limited
- Requires considerable land space to construct
- Unsuitable where the ground water level is high or where soil conditions are rocky or prone to collapse
- Odour can be difficult to prevent

Sources:

Harvey, P. (2007). Excreta Disposal in Emergencies: A Field Manual. Retrieved 08 05, 2015, http://www.unicef.org/eapro/unprotected-EDEchapter4.pdf

Bucket Latrine

Working Principle

- Typically consists of a seat on top and an easily sealable bucket beneath to contain urine and faeces
- In some cases urine is diverted to a separate container

Performance

- Can be used anywhere
- Disinfectant can be added to reduce odour and kill pathogens

Estimated Cost

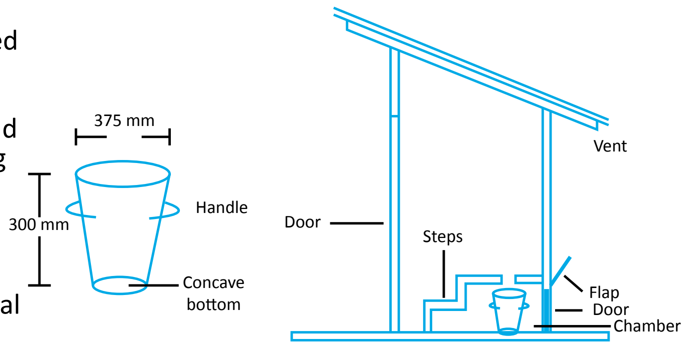
- Low cost, particularly if bought locally

Applicability

- Areas where there is no toilet access, flooded areas, areas with a high water table and other places where is no possibility for a toilet

Operations and Maintenance

- Buckets are replaced by workers on a daily basis
- A tightly fitting lid is fitted to the bucket which is transported to a central location for emptying and disinfection before being re-used
- Workers handling the buckets need to be well trained and equipped with appropriate personal protection equipment



Main Strengths

- Low cost
- Simple to procure
- Easy to transport
- Allows users to use the facility in the privacy of their own tent/home
- The only infrastructure required is for the final disposal and bucket cleaning system

Main Weaknesses

- High potential for spread of disease if not managed properly
- Some users may find using bucket latrines to be unacceptable
- Large quantities of containers and disinfectant are required
- Significant training may be required to properly operate a bucket latrine system

Sources:
Harvey, P. (2007). Excreta Disposal in Emergencies: A Field Manual. Retrieved 08 05, 2015, http://www.unicef.org/eapro/unprotected-EDEchapter4.pdf

Children's Faeces

Proper collection of children's faces is vital as children defecate indiscriminately and their faces is typically more infectious than adult faces. The following options can be used to collect children's faeces:

- Potties
- Disposable nappies including biodegradable versions
- Defecation trenches designed to enable children to defecate with the assistance of their parents
- Immediate clean up and burial of faeces from children defecating in the open by parents using digging tools

Sources:
Ferron, S., Lloyd, A. & Buttle, M. (2014). Emergency WASH for Children Scoping study. Retrieved 08 24, 2015, from Enhancing Learning and Research for Humanitarian Assistance: http://www.elrha.org/wp-content/uploads/2015/02/2014-10-11-Emergency-WASH-for-Children-Final.pdf
Wisner, B., Adams, J. Environmental Health in Emergencies and Disasters: a practical guide, chapter 8. Retrieved 08 24, 2015, from: http://www.who.int/entity/water_sanitation_health/hygiene/emergencies/em2002chap8.pdf?ua=1

Manual Tools

Working Principle

- Purpose built hand tools including buckets, long handle rakes, spades and corers are used dig and pull out FS
- Workers do not enter the containment structure themselves

Performance

- Effective at dealing with thick, difficult to pump FS and FS containing solid waste
- Slow compared to mechanized collection methods
- 1.2 m^3/h yield

Estimated Cost

- Low capital costs to set up
- Variable operating costs depending on context

Applicability

- Versatile, can be used in many different situations including where access is difficult and with all types of sludge

Operations and Maintenance

- Tools and equipment must be cleaned after use and protected from corrosion
- Tools and equipment can be manufactured and repaired locally

Main Strengths

- Use of simple tools and manual work is very sustainable
- Low cost
- Provides a source of income for local people
- Can remove thick FS

Main Weaknesses

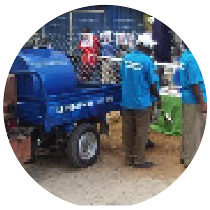
- Slow
- Socially unacceptable in some contexts, resulting in stigmatization of workers
- Potentially serious health risks to workers and community

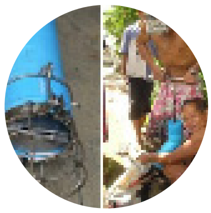
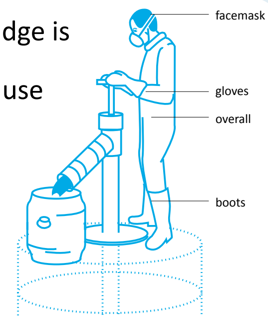
Sources:
Bhagwan, J., Wall, K., Kirwan, F., Ive, O., Birkholtz, W., & Shaylor, E. (2012, 10 31). Demonstrating the Effectivenes of Social Franchising Principles: The Emptying of Household VIPs, a Case Study from Govan Mbeki Village. Retrieved 01 30, 2013, from SuSaNa: http://www.susana.org/images/documents/07-cap-dev/b-conferences/12-FSM2/c7.3-fsm2-wall-ethekwini-municipality.pdf
Wall, K., Bhagwan, J., Kirwan, F., Ive, O., Birkholtz, W. Shaylor, E., Lupuwana, N. (2012). Demonstrating the Effectiveness of Social Franchising Principles. Retrieved 08 05, 2015, from: http://www.susana.org/images/documents/07-cap-dev/b-conferences/12-FSM2/c7.4-fsm2-ive-impilo-yabantu-south-africa.pdf
Annis, J., Gras, X., Rossi, F. (2015). The Efficacy of Low-cost Technologies to Improve Traditional Sludge Practices in Madagascar retrieved 08 05, 2015, from SUSANA: http://www.susana.org/images/documents/07-cap-dev/b-conferences/15-FSM3/Day-1/Rm-3/1-3-1-1-Annis.pdf

Phase 2

Gulper I

Working Principle	• Widely used, manually operated pump specially designed for pumping FS • Can be locally manufactured by skilled workshops • Operated from the surface without needing to enter the containment structure • The operator pushes and pulls a piston or lever type handle, which opens and closes a set of valves that lift FS up a riser pipe where it is discharged through a spout into a container • A strainer at the pump inlet is designed to stop solid waste from entering and blocking the pump
Performance	• Pumping depth varies depending on the model used • The pumping rate is approximately 15 l/min • Less suited to pumping thick sludge
Estimated Cost	• The cost varies from 40 to 1,400 USD
Applicability	• Suitable for more liquid FS • Can be used in areas where access is difficult such as narrow streets and alleys. • Unsuitable for toilets with a small superstructure where lack of space makes set-up and operation of the pump difficult
Operations and Maintenance	• The pump is placed into the containment structure and sludge is pumped into buckets or drums for removal • The Gulper requires careful cleaning and disinfection after use



Main Strengths	• Easy to fabricate and repair with locally available skills and materials • Typically low capital cost • Easy to transport
Main Weaknesses	• Slow in operation • Despite the use of a strainer, solid waste can block the pump inlet • The riser pipe is prone to cracking with long-term use • Operation of the Gulper can result in splashing of sludge in the vicinity of the pump leading to public health risks

Sources:

Annis, J., Gras, X., Rossi, (2015). The Efficacy of Low-cost Technologies to Improve Traditional Sludge Practices in Madagascar retrieved 08 05, 2015, from SUSANA: http://www.susana.org/images/documents/07-cap-dev/b-conferences/15-FSM3/Day-1/Rm-3/1-3-1-1-Annis.pdf
Boot, N. (2007). Talking Crap: Faecal Sludge Management in Accra, Ghana. Water, Engineering and Development Centre (WEDC). Loughborough, UK: Loughborough University. Godfrey, A. (2012). Faecal Sludge Management Demonstration Project in Maxaquene A and B, Maputo, Mozambique. Maputo: WSUP. 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.
Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publish- ing.

Gulper II (The Rammer) (Under Development)

Working Principle

- Able to pump thick sludge
- Pumps FS into a container with reduced splashing
- The pump can be extended to reach depths of up to 3m
- A long lever arm facilitates operation

Phase 2

Sources:
Malinga, S. (2015). Development of a low cost desludging pump in Uganda. Retrieved 08 05, 2015, from SUSANA: http://www.susana.org/images/documents/07-cap-dev/b-conferences/15-FSM3/Day -1/Rm-3/1-3-1-5-Malinga.pdf
Baker, M. Borderless Blog (2015). The Past and Future of Uganda's Sanitation: A Photo Essay. Retrieved 08 05, 2015, from: http://pyxeraglobal.org/the-past-and-future-of-ugandas-sanitation-a-photo-essay/

Diaphragm Pump

Working Principle	• A flexible diaphragm is alternately pushed and pulled by a lever similar to the action of a rubber plunger used to unblock a toilet or sink • A strainer prevents solid waste from entering the pump • The pump is typically mounted on a board which the operator stands on to hold the pump in place
Performance	• Flow rate ranges from 15 to 100 l/min • Pumping head of 3.5 to 4.5m
Estimated Cost	• 380-850 USD
Applicability	• Performs well with more liquid FS
Operations and Maintenance	• Must be thoroughly cleaned internally after use to avoid blockages

Main Strengths	• Simple design with relatively few moving parts • Effective at quickly pumping low viscosity FS • Can be transported by one person
Main Weaknesses	• Entrainment of air can make priming the pump difficult and affect pumping performance • Spare parts are often not available locally • Cracking of the rubber diaphragm can occur • Clogging when pumping FS with a high solid waste content

Sources:
Annis, J., Gras, X., Rossi, (2015). The Efficacy of Low-cost Technologies to Improve Traditional Sludge Practices in Madagascar retrieved 08 05, 2015, from SUSANA: http://www.susana.org/images/documents/07-cap-dev/b-conferences/15-FSM3/Day-1/Rm-3/1-3-1-1-Annis.pdf
Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publish- ing.
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.

Motorised Diaphragm Pump

Working Principle

- A motorized diaphragm pump operates on the same principle as a manual diaphragm pump but is driven by electric or hydraulic motors or petrol or diesel engines

Performance

- Flow rate of 300 to 330 l/min
- Pumping head is typically 15m
- Light enough to be transported by one or two persons, in some cases the pumps are mounted on wheels for ease of transport

Estimated Cost

- Cost can range from 2,000 - 20,000 USD

Applicability

- Suitable for liquid sludge containing solid particles ranging from 40 to 60mm

Operations and Maintenance

- Operation and maintenance are similar to a manual diaphragm pump with additional requirements for the motor/engine
- Requires fuel or electricity to operate

Main Strengths

- Simple
- Low cost
- Easily transportable
- High flow rate

Main Weaknesses

- Tendency to clog easily when pumping FS with a high solid waste content
- Difficulties in keeping air-tight seal at fitting resulting in air entrainment and consequently low efficiency in solid sucking
- Difficulty in sourcing spare parts locally

Sources:

Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publish- ing.

Spit, J., Malambo, D, Gonzalez, M., Nobela, H., de Pooter, L., Anderson, K. (2014). Emergency Sanitation Faecal Sludge Treatment Field-work Summary. Retrieved 08 05, 2015, from: http://www.waste.nl/sites/waste.nl/files/product/files/20140613_field_trial_report.pdf

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.

Testing and developing of desludging units for emptying pit latrines and septic tanks; Results of nine months field-testing in Blantyre - Malawi. (2015). Retrieved 07 21, 2015, from UN Habitat: http://www.speedkits.eu/sites/www.speedkits.eu/files/Elaborate%20report%20field%20testing%20pit%20emptying%20Blantyre.pdf

Trash Pump

Working Principle

- Works in a similar way to centrifugal impeller water pumps. The impellers sometimes have sharp blades that can cut up material in the sludge to improve pumping

Performance

- The performance of the pumps differs depending on the size and model
- Pumps performance depends on model
- Can pump approximately 1,200 L/min

Estimated Cost

- 500 to 2,000 USD

Applicability

- Can pump approximately 1,200 L/min
- Maximum pumping heads of 25 to 30 meters

Operations and Maintenance

- The impellers' housing is usually simple and easy to remove allowing for rapid unblocking if and when required

Main Strengths

- Good for pumping sludge with a high liquid content

Main Weaknesses

- Difficulty in locally sourcing spare parts
- Some potential for clogging due to solid waste despite impeller blades

Sources:
MSF. (2010). Public Health Engineering in Precarious Situations. Médecins Sans Frontières (MSF).
Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publishing.

Pit Screw Auger (Under Development)

Working Principle

- Consists of an auger placed inside a riser pipe which extends below the bottom end of the pipe. A hydraulic motor mounted on top of the riser pipe turns the auger
- The hydraulic motor is driven by a petrol engine hydraulic power pack via hydraulic hoses which allow the power pack to be located up to 10 m from the pit screw auger
- The separate power pack reduces the weight of the auger and allows for forward and reverse drive
- Depth is adjustable to suit the containment structure

Performance

- Flow rate of 40 to 50 L/min

Estimated Cost

- 4,500 USD

Applicability

- Designed to work best with denser sludge

Operations and Maintenance

- Can be operated by one person (weighs between 20 and 40 kg)
- 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




Main Strengths

- Can pump sludge containing a small amount of solid waste (options are being trialed to improve this using a macerator head that can cut up solid waste to improve pumping)

Main Weaknesses

- Complicated emptying process due to the fixed length and rigidity of the auger and riser pipe
- Unsuitability for use in situations where there is large amounts of solid waste
- Difficulties with cleaning after use
- Difficulties maneuvering due to weight and size

Sources:
The "Excrevator" Safe and Effective Pit Emptying Tate Rogers, North Carolina State University, Raleigh. Retrieved 07, 20, 2015, from Sustainable Sanitation Alliance: http://www.susana.org/images/documents/07-cap-dev/b-conferences/15-FSM3/Day-2/Rm-1/2-1-3-6-Rogers.pdf
Rogers, T. (2014). Retrieved 07 21, 2015, from Sustainable Sanitation Alliance: categories/99-faecal-sludge-transport/4252-the- excrevator-power-auger-to-empty-pits-north-carolina-state-university-usa-now-field-testing? limit=12&start=24

Gobbler (Under Development)

Working Principle	• A continuous rotary action pump powered using a small electric motor. The motor turns a double chain drive that rotates metal scoops which are used to lift FS up a riser pipe. The FS is discharged at the top with the assistance of a scraper to remove the sludge from the scoops
Performance	• Pumping head of >3 m
Estimated Cost	• 1,200 USD
Applicability	• Suitable for pumping higher viscosity sludge
Operations and Maintenance	• The Gobbler is supported and moved into position on a tripod • Sludge is discharged into a drum or bucket 
Main Strengths	
Main Weaknesses	• Heavy • Fixed length so unable to empty pits of different depths • During operation sludge can block the drive chains • Complex fabrication process with a large number of parts

Sources:

STILL, D., O'RIORDAN, M., McBRIDE, A. and LOUTON, B. (2013) Adventures in search of the ideal portable pit-emptying machine. Retrieved 07 21, 2015, from Sustainable Sanitation and Water Management: http://www.sswm.info/sites/default/files/ ref-erence_attachments/adventures.pdf

Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publish- ing.

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.

Vacuum Trucks

Working Principle

- Vacuum pumps and a tank mounted on a truck chassis or on a trailer pulled by a tractor
- FS is pumped into the tank and transported to the treatment/disposal point

Performance

- Suitable for removing low-viscosity sludge
- Thicker FS can be removed using special suction techniques
- Ideal for transporting large quantities of sludge over long distances
- Pumping head varies depending on pump model used
- Some vacuum tankers are able to dewater sludge to reduce the volume for transport
- 10,000 to 55,000 liters capacity

Estimated Cost

- 10,000 to 100,000 USD depending on specification

Applicability

- Mostly used for services in planned settlements where the septic tanks and pit latrines are easily accessible and FS is fairly liquid without solid waste

Operations and Maintenance

- The truck should be parked close to the system as possible typically no more than 25 meters
- Secure the truck using wheel chocks
- Layout and connect the hoses from the truck to the tank or pit to be emptied.
- Open the tank or pit by removing the access ports or covers over the storage system
- Pump out sludge and clean the area
- Transport sludge to treatment/disposal point to discharge

Main Strengths

- Can collect and transport large volumes quickly over long distances
- Has a low potential for operator contact with FS, if operated correctly

Main Weaknesses

- Difficulty accessing high density areas due to vehicle size
- Difficult to maintain in low-income contexts due to specialized parts (especially for trucks fitted with dewatering systems)
- High cost
- Some tankers are not applicable with thick FS

Phase 2

Sources:

Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publish- ing.

Brikké, F., & Bredero, M. (2003). Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation. Retrieved 07 22, 2015, from WHO: http://www.who.int/ water_sanitation_health/hygiene/om/wsh9241562153.pdf

Vacuutug

Working Principle

- Vacuum tank and a pump run by a small petrol or diesel engine
- FS is pumped into the tank and transported for disposal
- A range of versions have been developed including a self-propelled chassis (right), a trailer mounted version towed by a tractor or pick up and a version mounted on a motorised tricycle chassis

Performance

- Capacity to remove FS (or urine) at 1,700 litres a minute
- 500 liters to 1,900 liter tank capacity

Estimated Cost

- 10,000 to 20,000 USD

Applicability

- For emptying FS from areas where conventional tanker trucks cannot access due to space limitations

Operations and Maintenance

- Only two operators are required to operate the machine
- A vacuum setting is used to pump FS into the tank
- A pressure setting is used to empty FS from the tank and to assist in unblocking the suction pipe as required
- For operation and maintenance there is user manual with the product

Main Strengths

- Is maneuverable and can access high density settlements
- Spare parts are easily available and the machine can be manufactured locally
- Costs 20% of a vacuum tanker
- The vacuum pump is very effective

Main Weaknesses

- Slow moving with a road speed of 5 km/h
- Poor hill climbing ability
- Low tank capacity
- Some reports of quality issues relating to the manufacturing process

Sources:

Brandberg, B. (2012) Evaluation of the Un-Habitat Vacutug Development Project Pit Latrine Exhausting Technology. Retrieved 07 21, 2015, from UN Habitat: http://mirror.unhabitat.org/downloads/docs/2527_1_595414.pdf

Testing and developing of desludging units for emptying pit latrines and septic tanks; Results of nine months field-testing in Blantyre - Malawi. (2015). Retrieved 07 21, 2015, from UN Habitat: http://www.speedkits.eu/sites/www.speedkits.eu/files/Elaborate%20report%20field%20testing% 20pit%20emptying%20 Blantyre.pdf

ROM 2

Working Principle

- Mobile desludging unit suited for mounting on lighter vehicles or trailers towed by any vehicle with a towing capacity of 1200 kg
- Petrol driven vacuum pump combined with a water pressure pump and nozzles for fluidizing sludge thick sludge to facilitate pumping

Performance

- Able to pump 800 litres of FS in 4 minutes over a maximum tested distance of 30m and an elevation of 2 m
- Can empty th FS tank in less than 1 minute
- Consumes an average of less than 0.2 litres of fuel per pit emptied
- 800 litre tank
- 15m suction hose (2 or inch)
- 2,500 l/min FS vacuum pump
- 15 l/min water pressure pump

Estimated Cost

- Approximately 18,000 USD (not including shipping)

Applicability

- For emptying FS from areas where conventional tanker trucks cannot access due to space limitations

Operations and Maintenance

- Daily fluids and filter inspections
- Weekly cleaning and checks for damage
- General maintenance and service after 250 uses

Main Strengths

- Very good quality, reliable and durable
- Machine includes integrated fluidiser to assist in desludging
- Can be towed or transported on a truck bed
- Simple to repair in the field
- Excellent fuel economy

Main Weaknesses

- The setup of the suction probe is too cumbersome
- The equipment is too heavy for the operator, both for suction and fluidising
- The fluidizing nozzle is too big to fit into many drop holes.
- Requires well trained staff to operate
- There is a lack of spare parts support for vacuum section

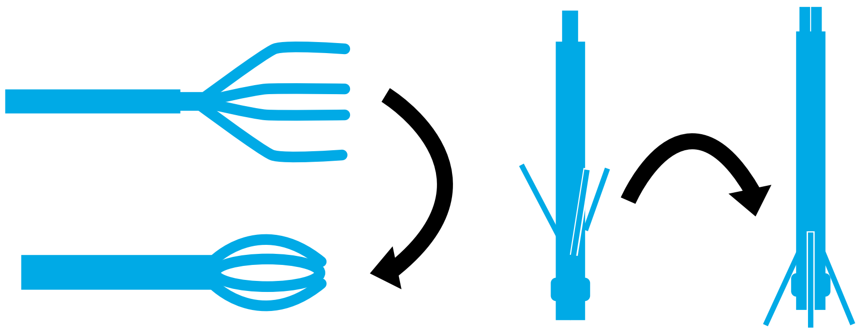
Sources:

ROM KOKS Group (N.D.). Retrieved 07 22, 2015, from ROM KOKS Group: http://www.rombv.com/rom-mobile-desludging-unit-3

Testing and developing of desludging units for emptying pit latrines and septic tanks; Results of nine months field-testing in Blantyre - Malawi. (2015). Re- trieved 07 21, 2015, from UN Habitat: http://www.speedkits.eu/sites/www.speedkits.eu/files/Elaborate%20report%20field%20testing%20pit% 20emptying%20 Blantyre.pdf

Fishing

- In order to facilitate pumping solid waste is first removed from the FS
- Specially designed hook and claw tools fitted to a steel pipe are used to remove the solid waste
- Fishing takes on average 30 minutes per containment structure
- It is not possible to fish out some objects such as stones and where these remain, they can occasionally block pump inlets


Claw Hook

Sources:
Testing and developing of desludging units for emptying pit latrines and septic tanks; Results of nine months field-testing in Blantyre - Malawi. (2015). Retrieved 07 21, 2015, from UN Habitat: http://www.speedkits.eu/sites/www.speedkits.eu/files/Elaborate%20report%20field%20testing%20pit%20emptying%20Blantyre.pdf

Fluidising

- Thick FS can be too solid to be pumped out. Tradi- tionally, large quantities of water are added to the containment structure and mixed with the FS to make it more flu- id. The large quantity of water adds significantly to the cost of the operation and can cause unlined containment structures to collapse
- A high pressure water pump (100 bar) and special nozzles are used to fluidise the FS for pumping using significantly less water than the traditional method
- The initial fluidising lasts for 10 - 15 minutes. Further fluidizing may be necessary during emptying

Manual Transport

Working Principle

- FS is manually transported over short distances in bins or sealed drums on standard or purpose built hand trollies and carts

Performance

- Can allow containers of up to 200 liters to be moved over short distances with relative ease

Estimated Cost

- Typically inexpensive, depending on local conditions

Applicability

- Suitable for transporting FS over short distances to a point accessible by a vehicle for bulk transport

Operations and Maintenance

- Simple to operate and maintain
- Can be repaired locally using locally available spare parts

Main Strengths

- Inexpensive
- Easy to fabricate and repair locally
- Allows FS to be moved from locations where access and space is very limited

Main Weaknesses

- Low capacity
- Slow transport speed

Phase 1

Phase 2

Sources:

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.

Motorised Transport

Working Principle

- Transport by small to medium motor vehicles including motor tricycles pick-up trucks
- FS can be transported in individual sealed containers or in a single large tank mounted on the load bed of the vehicle

Performance

- Motorised tricycles are capable of transporting up to approximately 1,000 liters of FS
- Pick-up trucks can transport between 2,000 and 5,000 liters of FS

Estimated Cost

- Country dependent

Applicability

- Suitable for transport of FS over longer distances

Operations and Maintenance

- The standard operation and maintenance requirements for these multi-purpose vehicles

Main Strengths

- Motorised vehicles are locally available and are multi purpose rather than being dedicated to transporting FS
- Enables transport of FS in larger volumes and over greater distances at higher speeds than manual transport

Main Weaknesses

- Smaller capacity than purpose built tanker trucks and trailers
- Cannot access highly densely populated areas

Sources:
Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Managment: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publishing.

Phase 1 Phase 2

Guiding Principles

- Intermediate storage can assist in optimizing the transport of FS to the final treatment/disposal point
- Smaller capacity transport systems for FS such as hand carts and trollies, are able to access areas that larger conventional equipment such as tanker trucks cannot but they are inefficient and impractical for transporting FS over longer distances
- Intermediate storage enables the aggregation of FS for on ward transport by larger faster vehicles

Sources:
Mikhael, G., Robbins, D. M., Ramsay, J. E and Mbéguéré, M. (2014) Methods and Means for Collection and Transport of Fecal Sludge in Fecal Sludge Managment: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publishing.

Tanks

Working Principle

- Solid walled container with inlet/outlet and valves to control FS flow.
- Constructed from a variety of different materials including plastic, fiberglass and steel

Performance

- Tanks vary in size and capacity to suit needs

Estimated Cost

- 24,00 litres - 17,000 USD / 1,000 litres, 150 USD

Applicability

- Suitable for intermediate storage of FS

Operations and Maintenance

- Sludge can be poured or pumped into the tank. Removal of sludge can be via pumping or by gravity
- Tanks should be regularly inspected for damage and any leaks
- Where FS containing solid waste is to be transferred into the tank use of a screen may be advisable to prevent the solid waste from entering the tank which might lead to blockages at the outlet

Main Strengths

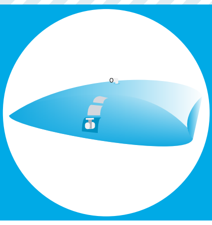
- Robust
- Quick to set up
- Modular, enabling more tanks to increase capacity as required
- Can be moved to different locations

Main Weaknesses

- Silt at the bottom of tanks may need to be periodically removed to avoid reductions in tank capacity

Sources:

Boot, N. (2007). Talking Crap: Faecal Sludge Management in Accra, Ghana. Water, Engineering and Development Centre (WEDC). Loughborough, UK: Loughborough University.



Bladders

Working Principle

- A flexible double skinned container that can filled and emptied through a valve
- Sited in a trough/depression in the ground in order to contain any leakage of FS

Performance

- Bladders vary in size and capacity to suit needs. Bladders with a capacity of 10,000 to 15,000 liters have been used for intermediate storage of sludge

Estimated Cost

- No data

Applicability

- Suitable for intermediate storage of sludge in one location

Operations and Maintenance

- The double skin of the bladder must be carefully maintained to avoid punctures
- The outer skin can be repaired but the inner skin cannot
- For safety and security reasons the bladder should be positioned in a level trench

Main Strengths

- Large capacity and easy to set up.
- Easy to fill and empty
- No odour issues

Main Weaknesses

- Risk of puncture resulting in leakage of FS than tanks
- Can roll if sited on a slope

Sources:

Spit, J., Malambo, D, Gonzalez, M., Nobela, H., de Pooter, L., Anderson, K. (2014). Emergency Sanitation Faecal Sludge Treatment Field-work Summary. Retrieved 08 05, 2015, from: http://www.waste.nl/sites/waste.nl/files/product/files/20140613_field_trial_report.pdf

Phase I

Disinfection

Working Principle

- Biological and chemical treatment of FS
- Three separate treatment processes are available: Lactic Acid Fermentation (LAF), a biological treatment; Urea Treatment (UT), a bio-chemical treatment and Hydrated Lime Treatment (HLT) a chemical treatment
- Further treatment can be carried out using other processes, if required

Performance

- All three treatment processes have the potential to be used to sanitize FS during an emergency situation to comply with the WHO guideline limit of 103 E-coli CFU/100ml
- The treatment time: LAF 7-15 days, UT 4-8 days, HLF 2 hours

Estimated Cost

- Per m^3 of FS: LAF 2.40 USD/m^3, UT 17.5 USD/m^3, HLF 13.1 USD/m^3

Applicability

- Suitable for emergency situations including unstable soils, high water tables and flood-prone areas where space is a constraint
- Can treat both liquid and solid sludge
- HLF is the fastest method. UT has the potential for re-use of FS and LAF is the most cost effective

Operations and Maintenance

- Can take place in an above ground tank, bladder or pit
- Material should be stored in a secure storage area to avoid people coming into contact with it
- Personal protection equipment including safety glasses/goggles, rubber gloves, face mask, overalls and rubber boots must be worn while working with these processes

Main Strengths

- Low-tech using readily available materials (urea is a common fertilizer and hydrated lime is a building material)
- Can be rapidly set up in an emergency
- UT has the potential to enable re-use of FS
- Potential for purchase materials from local suppliers

Main Weaknesses

- The efficiency of LAF and UT is very dependent upon temperature
- HLF requires homogeneous mixing to ensure that a completely sanitised sludge is produced
- Hydrated lime can cause irritation to the respiratory tract and permanent eye damage. Contact with the skin can lead to dermatitis and can cause burns in the presence of moisture
- Contact with Lactic acid can irritate the skin and damage eyes
- Urea can cause irritation to the skin, eyes, and the respiratory tract

Sources:

Spit, J., Malambo, D, Gonzalez, M., Nobela, H., de Pooter, L., Anderson, K. (2014). Emergency Sanitation Faecal Sludge Treatment Field-work Summary. Retrieved 08 05, 2015, from: http://www.waste.nl/sites/waste.nl/files/product/files/20140613_field_trial_report.pdf

Disinfection of Cholera Faeces

Faeces from cholera treatment centers are very hazardous and should be disinfected with chlorine

Procedure

- Prepare a 2% chlorine solution (using 65- 70% HTH powder, 30g of powder should be mixed with 1 liter of water)
- Pour the 2% solution into bedpans or buckets containing faeces and leave for 10 minutes before emptying into a covered pit
- 2% solution is stable for one week once prepared

Precautions

- Rubber gloves, rubber boots, protective suit, face mask and safety glasses must be worn when handling and disinfecting cholera faeces

Phase 1
Phase 2

Sources:
Lamond, E. & Kinyanjui, J. (2012). Cholera Outbreak Guidelines. Oxfam. Retrieved 08 05, 2015, from:
http://oxfamilibrary.openrepository.com/oxfam/bitstream/10546/237172/1/ml-cholera-guidelines-

Sanitary Landfill

Working Principle

- Dewatered faecal sludge is disposed of through burial in a sanitary landfill together with other municipal waste
- The waste is disposed of in layers which are filled, compacted and covered in an engineered pit
- The pit is lined at the bottom to prevent groundwater pollution
- Leachate (the liquid that drains or 'leaches' from a landfill) is collected and treated
- Some landfills are designed to promote anaerobic biodegradation of the organic portion of the waste in order to produce biogas

Performance

- A suitable disposal option provided that it is a well managed sanitary landfill
- It can be used for small communities and large cities provided that it is sited away from where people live
- Has the potential to dispose of large quantities of FS

Estimated Cost

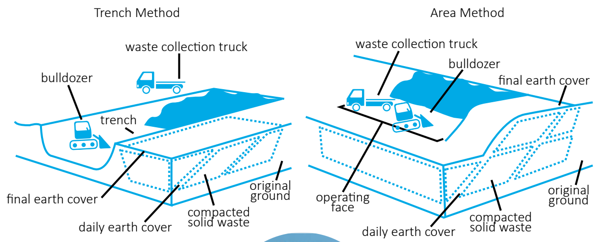
- Costs vary depending on local conditions however a landfill can be a cost effective solution for developing countries

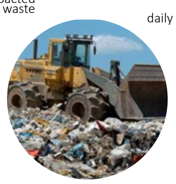
Applicability

- Where an existing sanitary landfill is located nearby or a suitable space exists to create a sanitary landfill
- When there is no end use or market for treated FS
- For FS that has a moisture content of < 80%

Operations and Maintenance

- The waste material is compacted and covered with soil or other material on a daily basis by heavy machinery in order to isolate the waste from the outside environment
- Negative impacts on public health and the environment are minimized through control measures such as managing the leachate and gas produced by the waste





Main Strengths

- An effective disposal method if managed well
- Does not require such rigorous treatment as compared to that needed for certain end uses of FS such as for food crops that are not cooked

Main Weaknesses

- Can be difficult to meet the requirements of compaction, daily covering of waste and control of public health and environmen- tal impacts in developing country contexts, leading to environ- mental pollution and water pollution
- Some existing landfills may be unwilling to accept FS
- A reasonably large area is required
- Sanitary landfills require expert design and skilled operators
- Once the landfill site is shut down O&M and monitoring must continue for the following 50 to 100 years

Sources:

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.

Klingel, F., Montangero, A., Koné, D. and Strauss, M. Fecal Sludge Management in Developing Countries: A planning manual. Retrieved 08 05, 2015, from: http://ocw.unesco-ihe.org/pluginfile.php/658/mod_folder/content/0/Faecal_Sludge_Management_in_Developing_Countries_-_A_planning_manual_.PDF?forcedownload=1

Drying Beds

Working Principle

- FS is dewatered through loading onto beds of sand and gravel with underlying drains, in some cases planted with wetland plants Dewatering occurs through three processes: percolation of the liquid or leachate through sand and gravel and out via the underlying drain; evaporation; and in the case of planted drying beds, evapotranspiration
- The leachate must be treated before being discharged
- Further treatment of the dried FS may be required depending on the final disposal option used

Performance

- 100 - 200 Kg TS /m^2 / year depending on local conditions
- FS can be applied in a layer of up to 20 to 30 cm thick at a time
- Drying time is variable depending on loading and local conditions
- Treatment efficiency (source?)
  - -Suspended solids: >=95%
  - -COD 70 to 90 %
  - -Helminthes eggs 100 %
  - -NH4 40 to 60 %
- Planted beds are more effective at removing pathogens than unplanted beds

Estimated Cost

- Depends on local construction materials

Applicability

- Suitable for dewatering FS and also for pathogen removal (planted drying beds)

Operations and Maintenance

- Simple operation, no skilled personnel required
- A splash plate should be used for application of FS to prevent erosion of the filter layer (in planted beds, the roots help to stabilize the filter layer)
- Sludge is removed by shovel and wheel barrow
- In the case of unplanted beds, dried sludge must be removed frequently and the sand will need to be replaced periodically as it becomes clogged with by solid matter (the removal of dried FS from the bed also results in the loss of some sand)
- Planted beds only require sludge to be removed every 5 to 10 years as the porosity of the filter is maintained by the plants
- Leachate must be treated before disposal
- Checking of drainage capacities

Main Strengths

- Any kind of sludge can be dewatered in drying beds
- A low technology approach that is simple to implement

Main Weaknesses

- Large land areas required to site drying beds
- Odour could be an issue; beds should be constructed far away from households
- Not adapted for areas prone to flooding
- A roof is required at locations with frequent rainfall
- Depending on the final disposal option further treatment of the FS may be required

Sources:

Kengne, I. &Tilley, E. (2014) Planted Drying Beds in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publishing.

Dodane, P. & Ronteltap, M. (2014) Unplanted Drying Beds in Fecal Sludge Management: Systems Approach for Implementation and Operation, edited by Strande, L., Ronteltap, M. and Brdjanovic, D. IWA Publishing.

Sphuler, D. (n.d.). Sustainable Sanitation and Water Management: Planted Drying Beds. Retrieved 08 05, 2015, from: http://www.sswm.info/ content/planted-drying-beds

DEWATS

Working Principle

- Natural aerobic and anaerobic digestion process
- Four modules for physical and biological treatment: Settler, Anaerobic Baffled Reactor and Gravel Filter
- Outlet flow should be peculated if ground conditions and proximity to water wells for drinking permit this

Performance

- Treatment of daily wastewater flows from $3m^3$ to $150m^3$ (Prefabricated DEWATS)
- Treatment efficiency:
  - 20% - 30% BOD reduction in settler
  - Up to 90% BOD reduction in Anaerobic Baffle Reactor
  - Up to 95% BOD reduction in Anaerobic Filter

Estimated Cost

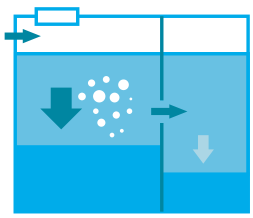
- 65-75 USD/person

Applicability

- Suitable for both domestic and industrial organic wastewater treatment with fluctuating inflows

Operations and Maintenance

- Documentation of septage characteristics
- Cleaning of screen chamber
- Operation of valves
- Regular (influent and effluent) sample collection for assessment of treatment efficiency
- Regular desludging of BGS
- Removal of sludge from SDB
- Harvesting of plants in PGF



Main Strengths

- The sewer pipes used for DEWATS are small and are shallowly buried, hence cost is reduced
- The O&M of the sewer system is easier due to its shallow depth
- Failure of the sewer system or treatment infrastructure affects only that particular area due to the decentralized nature of DEWATS
- Conveyance of wastewater is often possible through gravity flow rather than through pumping

Main Weaknesses

- The dispersed nature of treatment facilities at decentralized locations may make O&M of the facilities more challenging

Co-Composting

Working Principle

- Aerobic decomposition of dewatered FS mixed with other organic material with a high carbon content
- Microorganisms breakdown the material under thermophilic conditions
- The temperatures of 60-70 degrees C generated through the process break down the pathogens in the FS
- The compost product can be used in agriculture as a soil conditioner

Performance

- The composting process requires a minimum of 6 to 8 weeks to complete
- Capacity of co-composting systems can range from 2 tons per day for smaller decentralized systems up to 200 tons per day for larger centralized operations
- Co-composting produces a fiber-rich, carbon-containing humus with inorganic nutrients like nitrogen, phosphorus and potassium

Estimated Cost

- Capital and operating costs vary according to local conditions but are low
- During the post 2010 earthquake emergency in Haiti, 1.9 million liters of human waste was composted by Sustainable Organic Integrated Livelihoods (SOIL) with 69% of labour costs covered through the sale of compost at USD 123/m^3 (not including infrastructure costs)

Applicability

- Suitable where there is an available source of biodegradable solid waste, sufficient space and a demand for the end product

Operations and Maintenance

- The mixed material is formed into enclosed or open heaps which are aerated through special ventilation systems or by periodic manual turning of the heaps
- Optimal composting conditions require a carbon to nitrogen ratio of 20-30:1, an oxygen concentration of 5-10% and a moisture content of 40-60% by weight
- A ratio of 1:2 to 1:3 of FS to organic material should be used. Organic material for co-composting can include organic household waste. FS used for co-composting should have a TS > 20%



Main Strengths

- The end product is a valuable resource
- A high removal of helminth eggs is possible in the right conditions (< 1 viable egg/g TS)
- The infrastructure is simple to construct and maintain using locally available materials
- No electrical energy required

Main Weaknesses

- Needs a large land area (in Haiti 0.6 ha for 10,000 people) and long storage times
- Requires expert design and operation by skilled personnel
- Compost markets must be nearby as it is uneconomic to transport compost over long distances

Sources:

Tilley, E., Lüthi, C., Morel, A., Zurbrügg, C., Schertenleib, R. (2014). Compendium of Sanitation Systems and Technologies. Swiss Federal Institute of Aquatic Science and Technology (EAWAG) and WSSCC. Dübendorf, Switzerland. 2nd revised edition. Available from www.sandec.ch.

Kramer, S., Preneta, N. & Kilbride, A. (2013). Thermophilic composting of human wastes in uncertain urban environments: a case study from Haiti. 36th WEDC International Conference, Nakuru, Kenya. Available from http://www.oursoil.org/wp-content/uploads/2014/11/Thermophillic- composting-in-Haiti.pdf.

Equipment and Protocols

Personal Protection Equipment

- One piece overalls made of washable fabric
- Rubber gloves
- Rubber boots
- Face masks (nose and mouth) - disposable
- Eye protection
- Soap for washing hands

Safety Equipment

- Backpack sprayer for spraying chlorine solution to disinfect boots and equipment

Protocols should be established for:

- Putting on and taking off protective gear
- Unforseen situations where persons come into direct contact with FS
- Safe transport and cleaning of personal protection equipment and tools in order to prevent further contamination
- Provision of immunizations and 6 monthly deworming treatments for all workers
- Protection of the public from FS
- Environmental protection from cleaning chemicals and leachate from cleaning

Sources:
Louton, B. (2012). Pit Emptying and Public Health. Retrieved 08 05, 2015. from: http://www.susana.org/images/documents/07-cap-dev/b-conferences/12-FSM2/b6.1-fsm2-louton-partners-development-south-africa.pdf