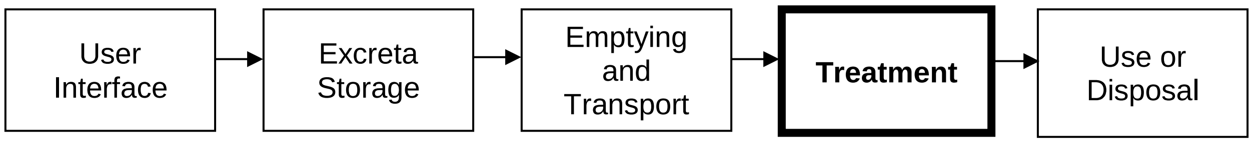
Technical Brief: Sanitation System – Fecal Sludge Treatment



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1 Introduction

A sanitation system deals with human excreta from the time it is generated until it is used or disposed of safely. The fourth component of the sanitation system addresses treating fecal sludge to reduce the health and environmental risks. A lack of available and low cost treatment options contributes to harmful fecal sludge being dumped into the environment. This reduces the benefits of building on-site sanitation technologies in the first place.

The type and level of treatment will depend on the final goal for the fecal sludge. Treatment can mean reducing the pathogens to a safe level. Or it can be transforming fecal sludge into a valuable product with economic and environmental benefits. Using a product rather than creating waste is called “resource recovery”. Treatment helps to manage and reduce negative impacts of fecal sludge, as well as increase the potential positive impacts.

This Technical Brief introduces the importance of fecal sludge treatment and explains different treatment objectives, including pathogen inactivation, dewatering, nutrient management, and stabilization. It also gives an overview of emerging and established technologies available to treat fecal sludge.

This document provides a technical overview and is not a design manual. An experienced professional should be consulted for the design of specific treatment technologies.

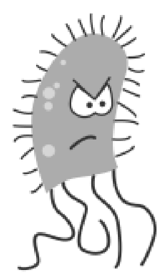
CAWST focuses on the planning, design, and implementation of on-site sanitation projects for low-income communities not connected to a sewer. For such communities, household or decentralized sanitation offers a hygienic and affordable solution.

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

2 What Are the Objectives of Treatment?

The type and level of treatment will depend on the final goal for the fecal sludge. There are four main treatment objectives: (1) pathogen inactivation, (2) dewatering, (3) stabilization, and (4) nutrient management.

1. **Pathogen inactivation:** A key objective of fecal sludge treatment is often pathogen reduction to protect public health. Pathogens are bacteria, viruses, protozoa and helminths that cause disease. The level of pathogen reduction required depends on the final use or disposal of the fecal sludge. For example, sludge applied to crops needs more treatment to reduce pathogens than if it is buried.



   Fecal sludge treatment inactivates pathogens in various ways. The mechanisms are described in CAWST’s Technical Brief: Fecal Sludge Treatment – Pathogen Inactivation Mechanisms.

More information about pathogens can be found in CAWST's Technical Brief: What is Fecal Sludge?

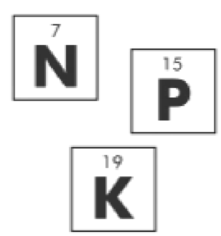
2. **Dewatering**: Fecal sludge naturally has a high water content. Dewatering removes water from the fecal sludge. The term drying is also sometimes used, and suggests an increased level of dryness. To understand the difference between dewatering and drying, think of a wet towel. You first have to wring the towel (dewatering), then you have to hang your towel to dry (drying).

   Water is heavy. Dewatering reduces the weight and volume of sludge making it easier, cheaper, and safer to manage. Dewatered sludge also attracts fewer vectors (like flies and rats) and can reduce smells. As well, the more water in fecal sludge, the higher the risk of surface and groundwater contamination. Pathogens in wet fecal sludge will infiltrate into the ground faster and travel farther than pathogens in dry fecal sludge

   Dewatering is sometimes needed before using other treatment technologies. For example, if you wanted to compost sludge from a septic tank, you would have to dewater it first. This is because the sludge from a septic tank is very wet, and composting is more efficient with drier sludge. However, not all sludge is easy to dewater. In general, sludge that has not been stabilized is more difficult to dewater (Strande et al., 2014).

3. **Stabilization:** Stabilized fecal sludge means that easily degradable organic material is degraded by microorganisms. Fecal sludge contains a lot of organic material, which can be beneficial for plants, or can be a contaminant in surface water. Stabilized sludge is more predictable, smells less, and contains nutrients that are in a form plants and microorganisms in the soil can more readily use.

   If your goal is to produce energy, you will want less stabilized fecal sludge to start with. The breakdown of organic material during stabilization produces energy. In an anaerobic setting, it will produce biogas. In an aerobic setting, it will generate heat. Less stabilized sludge has the potential to produce greater amounts of energy.



4. Nutrient management: Fecal sludge contains nutrients, like nitrogen, potassium, and phosphorous. These nutrients are needed for plant growth. Farmers apply them to increase crop yield. However, these nutrients can also infiltrate through soil into groundwater, or be transported by rainwater runoff to surface water bodies. They can contaminate both drinking water and the environment.

   Nutrient management generally means changing the form of nutrients (for example, from liquid to solid, or from organic to inorganic). Nutrients are not necessarily removed during treatment, but transformed. When organic material is stabilized, nutrients are also stabilized (meaning they are taken up and incorporated into organic material).

   The form of the nutrient is important for managing the fecal sludge and protecting the environment. For example, nitrogen in an organic form (for example, compost) is stable and slowly released. It can be directly applied to crops and beneficially used. Whereas nitrogen in an inorganic or ionic form (for example, nitrogen found in leachate) can have negative impacts. For example, it could harm plants when applied directly, move down through the soil to groundwater, or volatilize into the environment and cause harm.

3 Fecal Sludge Treatment Technologies

There are many technologies available to treat fecal sludge, each with different treatment objectives, treatment products, and level of development.

Fecal sludge treatment is a process. To effectively treat fecal sludge, several treatment technologies may be needed in a particular order. For instance, sludge may have a lot of water, which often needs to be removed before other technologies can be used, like composting or incineration.

The choice of technologies will largely depend on the following factors:

1. **Final goal:** It is important to keep the final goal in mind when selecting appropriate treatment technologies. You first need to know how the sludge will be used or disposed of so you know what treatment is required. For example, you need to focus on dewatering, stabilization and inactivating pathogens to a safe level if you are using fecal sludge for agriculture. However, if the goal is to produce energy, then dryness is important while pathogen inactivation may be a lower priority.

   For more information on use and disposal, see CAWST's Technical Brief: Fecal Sludge Use and Technical Brief: Fecal Sludge Disposal.

2. **Sludge characteristics and quantity:** Sludge from one on-site sanitation technology can be very different than sludge from a different technology. The composition of sludge (what's in it), as well as its consistency (how liquid or solid it is) and quantity will depend on various factors. These include the type and number of on-site sanitation technologies, amount of greywater added, emptying method, and climate. It is important to know the characteristics of the sludge to choose the appropriate treatment technologies. Some treatment technologies, for example, work better with dry sludge (like composting) while others treat wet sludge (like a settling-thickening ponds).

   For more information on sludge characteristics, see CAWST's Technical Brief: What is Fecal Sludge?

3. **Level of technology development:** The level of research and knowledge on treatment technologies can also influence technology selection. Some technologies are well established for fecal sludge treatment, while others are innovative and under development. As well, there are technologies that are being transferred and adapted from wastewater treatment or other sectors for fecal sludge treatment. There is more operational information available for established technologies.

4. **Other factors:** In any given context, the technology choice will also depend on financial resources, cost, local availability of materials, availability of space and land requirements, soil and groundwater characteristics, availability of a constant source of electricity, skills and capacity for design and operation, and management considerations (Tilley et al., 2014).

3.1 Solid Waste Removal

On-site sanitation technologies, like pit latrines, are often used as a garbage bin by users. A study done by the pollution research group in Durban, South Africa found various waste products in the latrines. They found plastics (soft and hard), hair wigs, menstrual products, cloth, glass, and metals (Velkushanova, 2015).

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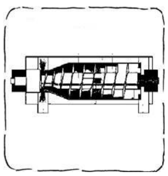
Solid waste needs to first be removed from the fecal sludge as part of the treatment process. It can be removed manually or by running the sludge through a screen.

3.2 Dewatering Technologies

The following tables summarize the different dewatering technologies available for fecal sludge.



Mechanical Dewatering		Transferring from wastewater treatment
Design: Mechanical dewatering technologies include belt filter press, frame filter press, screw press, and centrifuge. Mechanical forces dewater fecal sludge (for example, centrifugal force). **Operation:** Conditioners often need to be added to the fecal sludge before mechanical dewatering. Conditioners are products that help to dewater the sludge more efficiently.		
Level of Dewatering	**Level of Pathogen Inactivation**	**Stabilization and/or Nutrient Management**
High	Low	No

Planted Drying Bed		Established technology
Also called planted dewatering beds, vertical flow constructed wetlands, and sludge drying reed beds. **Design:** A planted drying bed is filled with filter material, usually gravel at the bottom and sand on top. Plants selected for a specific climate grow in the filter media. The bottom of the bed is sloped and lined with perforated pipes to drain away the liquid (called effluent). **Operation:** Planted drying beds operate (semi-)continuously. Fecal sludge is placed on the surface of the bed and the liquid flows through the sand and gravel. The majority of the solid portion of the sludge stays on the surface. Some of the remaining water in the sludge is removed by evapotranspiration. Sludge can be loaded on the beds without removal for a period of years. Depending on the retention time, the dewatered sludge is stabilized.		
Level of Dewatering	**Level of Pathogen Inactivation**	**Stabilization and/or Nutrient Management**
Medium	Medium	Yes

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Unplanted Drying Bed	Established technology

Also called sand drying bed.

Design: Unplanted drying beds dewater fecal sludge. An unplanted drying bed is filled with filter material, usually gravel at the bottom and sand on top. The bottom of the bed is sloped and lined with perforated pipes to drain away the liquid (called effluent or leachate).

Operation: Unplanted drying beds are operated in batches. Sludge is placed on the surface of the bed and the liquid flows through the sand and gravel for a period of days. The majority of the solid portion of the sludge stays on the surface. Some of the remaining water in the sludge is removed by evaporation. The dewatered sludge is then removed from the surface manually or mechanically.

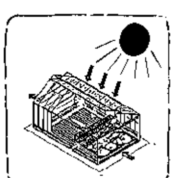
Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
High	Medium	No

Settling-Thickening	Established technology

Design: Settling-thickening technologies thicken and dewater fecal sludge. Solids settle to the bottom as the fecal sludge flows from one end of the pond or tank to the other. The liquid (effluent) flows through the outlet and requires further treatment. Some solids (for example, fats, oils, and grease) float to the top and form a scum layer. Example technologies include settling-thickening tanks, settlers, Imhoff tanks, and septic tanks.

Operation: Settling-thickening technologies operate (semi-)continuously. Settling-thickening technologies often include two lined ponds or tanks. While one is being operated, sludge thickens in the second. The sludge is then pumped out for further treatment.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
High	Low	No



Thermal Drying	Transferring from wastewater treatment

Design: Thermal drying technologies remove more moisture from dewatered fecal sludge.

Operation: Thermal drying technologies operate in batches, continuously or (semi-) continuously. Energy for drying can be solar or through other forms of energy, for example waste heat from industries. Solar drying usually takes place in a greenhouse with transparent covers. Sludge is spread on the floor in shallow basins. The temperature in the greenhouse increases with sunlight and the water in the sludge evaporates. The greenhouse needs to have good ventilation to remove the moist air.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
Medium	Medium	No

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3.3 Stabilization and Nutrient Management Technologies

Anaerobic Digestion	Transferring from wastewater treatment

Also called a biogas reactor.

Design: Anaerobic digestion stabilizes fecal sludge. It converts fecal sludge into (1) biogas that can be used for energy, and (2) a slurry that can be used as fertilizer.

Operation: Anaerobic digestion is operated (semi-) continuously. Fecal sludge goes in an airtight reactor. Microorganisms break down the organic material in fecal sludge in the absence of oxygen (anaerobic conditions). This process produces methane, also called biogas. Some part of the fecal sludge remains in the reactor following breakdown. This is called digestate and needs to be removed for continuous operation. Fecal sludge can be co-digested with organic material (like food waste and animal excreta) to increase the volume of biogas. Anaerobic digestion is a delicate process to operate, and can be easily upset.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
None	Low	Yes

Black Soldier Fly Larvae	Innovative technology

Design: Black soldier fly larvae eat fecal sludge, and in doing so they reduce the volume and stabilize the sludge. Black soldier fly larvae are rich in fat and protein. They are fed to livestock as a source of protein. A black soldier fly does not need to eat once it can fly - in fact it does not have a mouth. Therefore, they are not a vector and do not spread pathogens.

Operation: Black soldier fly larvae treatment is done in batches or semi-continuously. Fecal sludge is placed in a container with black soldier fly eggs or larvae. Other organic waste streams can be added as well to be co-treated. The larvae are harvested periodically to feed to livestock.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
None	Low	Yes

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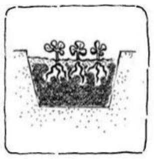
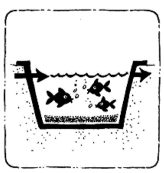


Deep Row Entrenchment	Established technology

Design: Deep row entrenchment is a method of disposal and use as a soil amendment. It requires careful design and operation to not contaminate groundwater.

Operation: Deep row entrenchment is done in batches. Untreated fecal sludge is placed in trenches and then covered with soil. Trees are planted on top or next to the trench. The length and the depth of the trench depend on the highest groundwater level and the quantity of fecal sludge. The trench can be lined, for example with a layer of clay, to reduce the risk of groundwater contamination.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
Low	Low	Yes



Fish Pond	Innovative / Transferring from wastewater treatment technology

Design: Fish ponds provide a rich habitat for fish, such as carp, to feed on aquatic plants and organisms. Solids settle to the bottom as the fecal sludge flows from one end of the pond or tank to the other. The liquid (effluent) flows through the outlet and requires further treatment.

Operation: Fish ponds are lined to prevent groundwater contamination. The settled sludge is periodically pumped out for further treatment. Fish and aquatic plants are harvested frequently. The fish can be used as animal feed. Fish must be cooked well if used for human consumption.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
Low	Low	Yes

Incineration	Transferring technology

Design: Incineration means that dry fecal sludge is converted into ash at high temperatures (between 850-900ºC). Incineration reduces the sludge volume and kills all pathogens. The ash can be buried, or used for construction material or as a cover material. Dried fecal sludge can fuel industrial processes, such as cement kilns. Incineration produces air emissions, which needs to be controlled to avoid negative environmental impacts.

Operation: Sludge needs to be dewatered before it is incinerated.

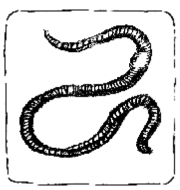
Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
High	High	Yes

Plant Pond	Innovative / Transferring from wastewater treatment technology

Design: Plant ponds grow aquatic plants using the nutrients in fecal sludge, such as duckweed, watercress, water spinach and water mimosa. Solids settle to the bottom as the fecal sludge flows from one end of the pond or tank to the other. The liquid (effluent) flows through the outlet and requires further treatment.

Operation: Plant ponds are lined to prevent groundwater contamination. The settled sludge is periodically pumped out for further treatment. Aquatic plants are harvested frequently. They can be used as animal feed.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
Low	Low	Yes

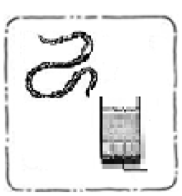


Vermicomposting	Innovative / Transferring from wastewater treatment technology

Design: Vermicomposting stabilizes dewatered fecal sludge. Composting worms break down the organic material as it passes through them. Vermicomposting produces a soil conditioner, which is considered a type of compost.

Operation: Vermicomposting is done in batches or semi-continuously. It requires a bedding layer such as woodchip or straw. The process produces effluent. At a small scale, it can be done in a dark, well-ventilated container, and the effluent is drained. At a large scale, vermicomposting is done in covered piles or rows, and the effluent seeps into the ground.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
None	Low	Yes



Vermifilter	Innovative / Transferring from wastewater treatment technology

Design: Vermifilters are filters which contain composting worms. The fecal sludge is added directly to the filters where the composting worms and environment stabilizes the fecal sludge through vermicomposting. Vermicomposting stabilizes dewatered fecal sludge. Composting worms break down the organic material as it passes through them. Vermifilters require a layer of bedding material (where the worms live) and a filtration layer. The bedding material must be made of organic material, such as woodchips. The filtration layer may be made from a variety of materials, such as gravel.

Operation: Vermifiltration is done semi-continuously.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
Low	Low	Yes

3.4 Pathogen Inactivation

Co-composting	Established technology

Design: Co-composting stabilizes fecal sludge and inactivates pathogens. Microorganisms break down the organic material in the presence of oxygen. If the process is properly controlled, the temperature of the pile increases resulting in pathogen inactivation, otherwise additional storage or curing is needed to reduce pathogens. The process produces compost, a dark, rich soil-like material, which can be used as a soil conditioner.

Operation: Co-composing is done in batches. Fecal sludge and other organic material (for example, food waste, wood chips) are placed in piles or rows. Various parameters need to be controlled to ensure an optimal composting process, including temperature, moisture, carbon to nitrogen ratio, and oxygen concentration.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
Low	High	Yes

Alkaline Treatment	Transferring from wastewater treatment technology

Design: Alkaline treatment increases the pH of fecal sludge and inactivates pathogens, if correctly dosed and mixed. Adding alkaline chemicals is also used to reduce smells, moisture, and flies.

Operation: Alkaline treatment is usually done in batches. A recommended dosage of alkaline chemicals, such as lime or ash, are added to the fecal sludge and mixed. Dosing depends on the alkaline chemical, sludge water content, and quantity of sludge.

Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
None	High	No

Ammonia Treatment	Innovative technology

Design: High ammonia concentrations are toxic for pathogens and inactivates them. Ammonia could be used from urine or fertilizer.

Operation: Urea is mixed with fecal sludge in batches. Dosing depends on the required urea concentration, sludge water content, and total solids.

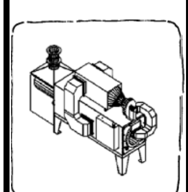
Level of Dewatering	Level of Pathogen Inactivation	Stabilization and/or Nutrient Management
None	More research is required	No

Storage		Established technology
Design: Fecal sludge is safely stored to inactivate pathogens. Storage must be planned and monitored, and it is not recommended over other fecal sludge treatment options. **Operation:** Storage is done in batches or (semi-)continuously. Dried fecal sludge is stored in a designated dry area. The conditions must be conducive for pathogen reduction (for example, dryness or temperature) and monitored since specific operating conditions are unknown.		
Level of Dewatering	**Level of Pathogen Inactivation**	**Stabilization and/or Nutrient Management**
Low	High	No

Note: The level of inactivation is based on the proper operation and maintenance of a treatment technology. If a technology is not operated correctly, then the treatment level will be lower.

3.5 Other

Co-treatment with Wastewater		Transferring from wastewater treatment technology
Design: Effluent from fecal sludge treatment technologies usually needs further treatment before discharge into water bodies or use for irrigation. Effluent treatment technologies include waste stabilization ponds, anaerobic baffled reactors, constructed wetlands (also called planted gravel filters), planted drying beds, and anaerobic filters. Effluent can be treated with or without wastewater **Operation**: These technologies cannot be used for treating fecal sludge, but rather effluent coming from other treatment technologies (except planted drying beds).		
Level of Dewatering	**Level of Pathogen Inactivation**	**Stabilization and/or Nutrient Management**
Depends on technology	Depends on technology	Depends on technology



Pelletizing		Transferring from animal feed or biomass fuel production
Design: Dewatered sludge is processed into pellets by pressing it through a nozzle or plate. Pellets are dense, consistent in composition, and relatively easy to store, transport, and market. **Operation:** Pelletizing can be used to enhance drying, for example with the Bioburn process that can process pellets at 50% moisture, that can then dry to 90% without additional thermal energy. Other pelletizers dewater or dry sludge when they are combined with other technologies, such as a thermal dryer in the LaDePa technology. Other pelletizing technologies require that the sludge is first dried, and then compressed into pellets with a binder.		
Level of Dewatering	**Level of Pathogen Inactivation**	**Stabilization and/or Nutrient Management**
Low	Low to High	No

4 Operation and Maintenance

Even well designed treatment technologies often fail because of poor operation and maintenance (O&M). Operation and maintenance can be defined as the following:

- **Operation:** All the activities that are required to ensure that a fecal sludge treatment technology delivers treatment services as designed. Examples of common operations activities are:
    - Adding sludge on to drying beds
    - Removing sludge from settling tanks
    - Removing sludge from drying beds
    - Controlling and emptying screening process
    - Processing (like mixing during composting or adding lime)
    - Collecting and further treating or disposing effluent
    - Storing and selling the treatment products
- **Maintenance:** All the activities that ensure long-term operation of equipment and infrastructure. Examples of common maintenance activities are:
    - Cleaning
    - Controlling corrosion
    - Repacking and exercising valves
    - Oiling and greasing mechanical equipment (for example, pumps)
    - Servicing mechanical equipment (for example, clearing pump screen)
    - Controlling vegetation and pests

Common operation and maintenance challenges observed globally include:

- Lack of financial viability
- Failure of equipment (for example, pumps)
- Weak material supply chains
- Poor operation and maintenance by service contractors (for example, removing sludge from ponds or tanks)
- Contamination from industrial sludge
- Electricity shortages
- Low capacity of staff
- Climate (for example, rainfall)
- Smells

The following table identifies possible solutions to overcome the most common operation and maintenance challenges. A key solution is to develop and implement a detailed operation and maintenance plan, and then have a monitoring program to ensure it is successfully implemented.

Table: Solutions to Overcome Common Operation & Maintenance Challenges

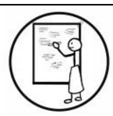
Improve financial viability	Prevent equipment failure	Improve material supply chains	Prevent contamination from industrial sludge
• Identify financial flows within the entire treatment process • Set appropriate sanitation taxes or discharge fees • Investigate or change market for treatment product • Investigate role of public-private partnerships	• Introduce Standard Operating Procedures (SOPs) for all equipment and treatment processes • Introduce a monitoring plan for treatment facilities • Set servicing intervals • Introduce servicing contracts • Increase servicing intervals	• Use materials which can be produced or obtained locally • Use equipment with locally available spare parts • Use equipment which can be repaired locally • Establish supply chains	• Monitor the influent to the treatment facility • Identify "upstream" sources of industrial sludge • Record the origin, volume and special characteristics of fecal sludge in a manifest system • Randomly measure the pH of fecal sludge during discharge • Train fecal sludge treatment operators on the physical inspection of sludge samples

5 Risk Management

Treatment is a barrier that can reduce the risk of pathogen transmission. However, it is difficult to monitor treated fecal sludge and know when it is pathogen-free. There is always a risk. It is therefore important that other protective measures be put in place.

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

Table: Protective Measures for Treating Sludge

Barriers to Protect Health		Action
	Use protective equipment	Wear protective equipment, such as clothing, gloves, shoes, and mask. Clean and disinfect the equipment used.
	Wash hands	Wash hands with soap after handling fecal sludge, tools, and equipment.
	Restrict access	Construct a fence to keep children and animals away from the treatment technology. Display warning messages.
	Clean tools	Disinfect the tools used. Safely store the tools so people do not touch them or use them for another purpose.
	Manage effluent	Treat and safely use or dispose effluent. Effluent contains pathogens and can contaminate the environment.
	Train	Train workers on safety precautions and hygiene practices. Train the local community on the purpose and potential hazards of the treatment technology.

Protective Measures used by SOIL, Haiti

SOIL is a nonprofit organization in Haiti that operates fecal sludge composting sites. After identifying the risks of disease transmission and at risk groups, they put in place various protective measures. These include the following:

- Signs are posted throughout the compost site to enforce rules for both staff and visitors. Examples of signs include: No food to be consumed on-site. All vehicles leaving site must disinfect tires. All pedestrians leaving site must disinfect shoes and wash hands.
- An on-site depot is available to store cleaning materials, miscellaneous construction materials, equipment items, and other items. The depot is secured and controlled by the site supervisor.
- Facilities are provided for the staff, including an individual changing room with a door for each staff member, shower, toilet, hand washing station, sanitary zone with table and chairs for resting and eating, and safe drinking water.
- Hygiene infrastructure is available for staff and visitors. This includes a chlorine footbath for disinfecting people’s shoes and a chlorine spray station for disinfecting vehicle tires before leaving the site.

(SOIL, 2011)

6 Scale of Treatment

Treatment technologies are generally appropriate for larger user groups (such as from semi-centralized applications at the neighbourhood level to centralized, city level applications). They are designed to accommodate increased sludge volumes and provide, in most cases, improved removal of nutrients, organics and pathogens, especially when compared with small household-level treatment technologies, like composting or dehydrating latrines (Tilley et at., 2014).

CAWST focuses on:

- Household level: treatment done on the household's property
- Community level: small-scale treatment done in the neighbourhood or community

For community level treatment, sludge must be brought to the treatment facility. See CAWST's Sanitation Technical Brief: Emptying and Transporting Fecal Sludge for more information on emptying on-site sanitation technologies and transporting fecal sludge.

7 Knowledge Gap

Knowledge on the various treatment mechanisms and technologies is limited. As research continues, the sanitation sector will grow its knowledge and skills in fecal sludge treatment mechanisms and technologies. The main gaps are the following:

- There is a lack of long-term experience with treatment technologies. Pilot projects on sludge treatment technologies have been carried out all over the world. They are extremely valuable, but are also often small-scale and short-term. This has slowed the sanitation sector from drawing conclusions on the effectiveness, cost, financial sustainability and scalability of different treatment technologies.
- Reliable data and accepted methods for characterizing and quantifying fecal sludge do not yet exist. As well, data from characterization studies also focus on the household level, whereas significant amounts of fecal sludge are generated at public toilets, commercial entities, restaurants and hotels (Strande et al., 2014).
- There are still unknowns about how some treatment technologies inactivate pathogens, particularly with newer technologies.

8 Definitions

Aerobic: Biological processes that occur in the presence of oxygen.

Anaerobic digestion: The decomposition and stabilization of organic material by microorganisms without oxygen. This process produces biogas.

Biogas: Mixture of gases released from anaerobic digestion (without oxygen). It is made up of 50–70% methane, 25–50% carbon dioxide, and varying quantities of nitrogen, hydrogen sulphide, water vapour and other components. Biogas can be collected and burned for fuel.

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

Dewater: The process of reducing the water content of fecal sludge. Dewatered sludge may still have a significant moisture content, but it is typically dry enough to be handled as a solid (for example, shovelled).

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

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

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

Organic material: Also called organic matter. Comes from the remains of living things, such as plants and animals.

Pathogen: An organism that causes disease.

Stabilization: Degradation of organic material with the goal of reducing readily biodegradable compounds to lessen environmental impacts (such as oxygen depletion and nutrient leaching).

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

Wastewater: Used water from any combination of domestic, industrial, commercial or agricultural activities, surface runoff (stormwater), and any sewer inflow (infiltration). Wastewater can be managed on-site or off-site. Wastewater managed off-site is often called sewage.

9 Additional Resources

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

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

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

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

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

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

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Akvo images can be retrieved at: http://akvopedia.org/wiki/Main_Page

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