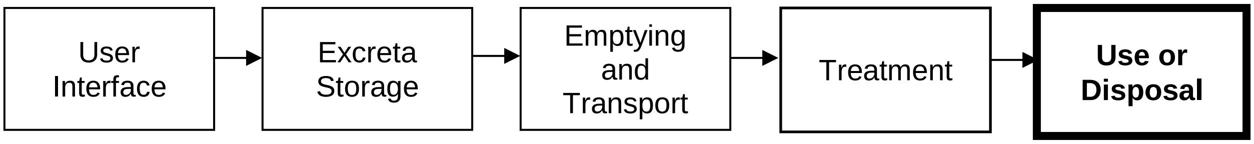
# Technical Brief: Sanitation System – Fecal Sludge Use




## Contents



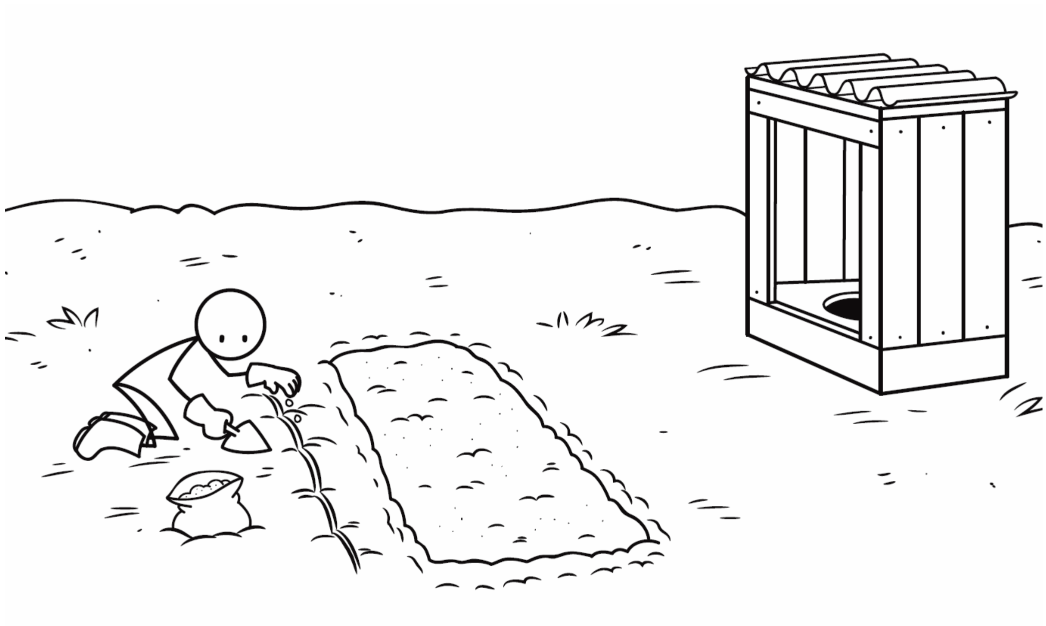
# Technical Brief: Sanitation System – Fecal Sludge Use

## 1 Introduction

A sanitation system deals with human excreta from the time it is generated until it is used or disposed of safely. This Technical Brief focuses on the fifth component of a sanitation system: using fecal sludge from on-site sanitation technologies, like a pit latrine or septic tank. As on-site sanitation increases, people are looking for innovative ideas and old traditions to use fecal sludge as a valuable resource.

This Technical Brief introduces the benefits and challenges of using treated fecal sludge for various purposes, including agriculture and energy production. It describes different beneficial uses, along with protective measures to reduce public health and environmental risks.

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



Using fecal sludge to grow plants

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.

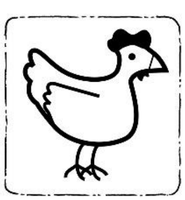
CAWST's free, open content resources and schedule of international training workshops can be found at: https://resources.cawst.org and www.cawst.org/training.

## 2 What Can Fecal Sludge Be Used For?

Fecal sludge is transformed by treatment technologies into various products. These treatment products can be a used in ways that have economic and environmental benefits. Using a product rather than creating waste is called “resource recovery”.

Historically, agriculture has been the most common use for fecal sludge. But research is being done on new ways to beneficially use fecal sludge. These uses are summarized in the following table.

**Table: Options for Using Fecal Sludge**

| **Fecal Sludge Use** | | **Description** |
|---|---|---|
|  | Agriculture and Horticulture | Treated fecal sludge is applied to soil as a soil amendment to improve plant growth by: (1) increasing nutrients, and (2) improving the physical structure of the soil. |
|  | Forestry | Treated fecal sludge is applied to soil to improve plant growth by: (1) increasing nutrients, and (2) improving the physical structure of the soil. |
|  | Irrigation | Effluent from on-site sanitation technologies and fecal sludge treatment technologies is used for irrigating crops to increase nutrients. |
|  | Energy (biogas) | Fecal sludge is mixed with organic waste (like food and garden waste) to produce biogas and digestate. Biogas is primarily used as an energy source for lighting, boiling water and cooking. |
|  | Energy (solid fuel) | Dried fecal sludge can replace other fuels, such as wood and charcoal, which are usually more expensive and damaging to the local environment. |
|  | Livestock | Animals, such as larvae, feed on fecal sludge and provide a protein source for other farm animals and fish. Plants produced from fecal sludge treatment technologies can also be fed to animals (for example, planted drying bed). |

| Fecal Sludge Use | | Description |
|---|---|---|
|  | Aquaculture | Aquatic organisms, such as fish and aquatic plants, feed on fecal sludge. These aquatic organisms can then be eaten directly, used as animal feed, or used as fertilizer. |
|  | Construction (building materials) | Dried fecal sludge is used to make cement and bricks, and to produce clay-based materials. |

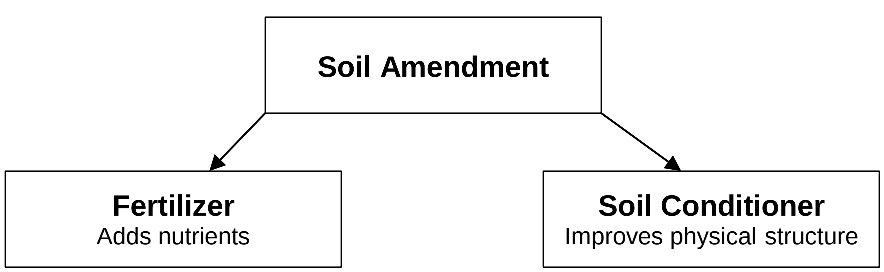
(Illustration credit: Akvo, n.d.)

## 3 Agriculture, Horticulture, and Forestry

Fecal sludge is most commonly used as a soil amendment in agriculture, horticulture, and forestry. A soil amendment is a general term for any material that improves soil quality. There are various reasons why soil can be of poor quality. The quality of soil can decrease naturally (for example, through erosion) or by human activity (for example, because of intensive agriculture practices). Common problems with poor soil quality include the following:

- Lack of nutrients
- Poor structure (for example, the soil is compacted)
- Cannot hold water
- High salt levels
- Too high or too low pH

Fertilizers and soil conditioners are two types of soil amendments. Fertilizers add nutrients to the soil that plants need to grow. Soil conditioners improve the physical soil structure by increasing the amount of pore space or making the soil less compact, which increases air and water movement and allows better root growth. Soil conditioners also provide a habitat for all the organisms that live below the ground. This ecosystem is vital for plant growth.



## 3.1 Fertilizers

Fertilizer is used to add nutrients to the soil because plants need nutrients to grow. The three main nutrients plants need, also known as macronutrients, are:

- **Nitrogen (N):** Needed for leaf and stem growth.
- **Phosphorous (P):** Needed for plants to grow flowers and fruits, to make plants more drought-resistant, and help the roots grow.
- **Potassium (K):** Important for root vegetables. It also helps plants resist disease and survive in harsh climates (like cold winters and droughts).

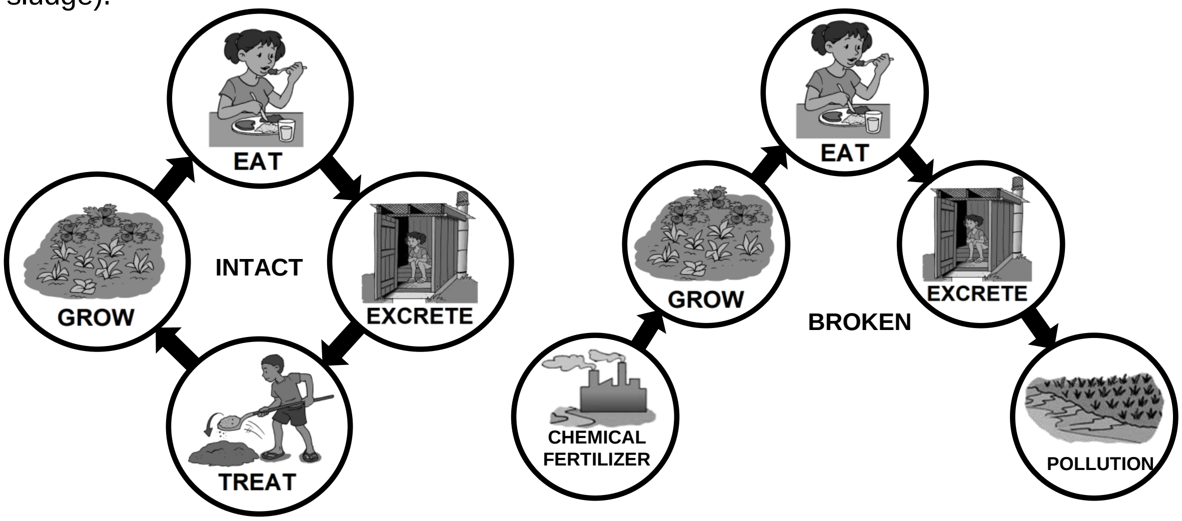
Different types of plants need different amounts of each nutrient. It is important that you know the nutrient demand of your crop. If the right amount of nutrients is applied, the weight of a crop can increase by 2–10 times (Winblad & Simpson-Hebert, 2004). However, too many nutrients can also be toxic for a plant.

To know how much fertilizer to apply, you will also need to know the amount of nutrients in the soil. Often fertilizer manufacturers and distributors for the region have determined this information. If this information is not locally available, you will have to do your own crop trials or use a soil test kit.

### *3.1.1 Nutrient Cycle*

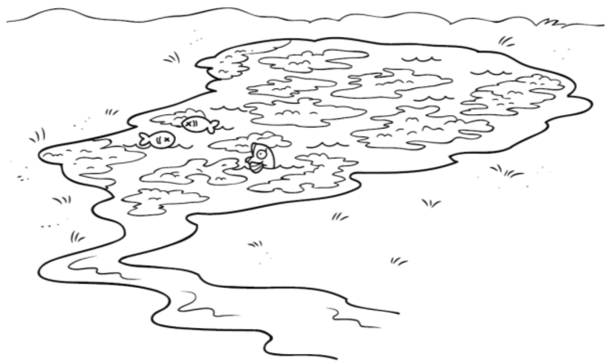
The nutrient cycle helps to explain why using fecal sludge is beneficial for plant growth and the environment. Plants use nutrients from the soil to grow. People and animals then eat the plants and excrete the nutrients through feces and urine. The nutrients in the excreta return to the soil so more plants can grow. However, nutrients are not always available in the form they need to be. Microorganisms need to break down the material and make the nutrients available to plants.

When people grow and harvest crops, many nutrients are removed from the soil. To return nutrients to the soil and continue to grow crops, farmers often add animal excreta (also called manure or dung). In many societies, it is also acceptable to use human excreta (or fecal sludge).




Intact and broken human nutrient cycles

However, in many parts of the world, we have broken this natural nutrient cycle. The nutrients in excreta are no longer returned to the soil to grow crops. Rather, they are often dumped or discharged into surface water bodies. Breaking the nutrient cycle has caused the following environmental and public health issues:


Eutrophication of surface water kills fish

- **Surface water quality:** High concentrations of nutrients and organic material in surface water damages the aquatic ecosystem and is disruptive to livelihoods (for example, fishing and tourism). Algae in the water feed on the nutrients and reproduce rapidly, called an algal bloom. The algae blocks the sunlight from penetrating the water, and other aquatic plants are unable to grow. When the algae dies and is eaten by other organisms, the oxygen in the water is used up and aquatic organisms (like fish) suffocate. This is known as eutrophication. When oxygen is depleted to low levels, this is called anoxic water.
- **Drinking water quality:** Nutrients can also contaminate drinking water and impact our health. For example, nitrates (a form of nitrogen) in drinking water can cause methemoglobinemia, a condition which decreases the amount of oxygen transported through our blood. Infants who are bottle fed with formula prepared with nitrate contaminated drinking water are most at risk. See CAWST's Fact Sheets on the Chemical Parameters of Drinking Water Quality for more information about nitrogen.
- **Soil quality:** Poor soil quality from the lack of nutrients leading to soil degradation.
- **Other forms of pollution:** Manufacturing chemical fertilizers consumes energy and creates other forms pollution.

### *3.1.2 Chemical Fertilizers*

Chemical fertilizers are known to contaminate the environment when poorly managed. But chemical fertilizers also have many advantages that shouldn't be ignored. They provide high crop growth rates and yields to meet the global food demand. Food grown with nitrogen fertilizers feeds an estimated two billion people worldwide (Fields, 2004). Chemical fertilizers are also easy to store, transport, and apply. As well, they are nutrient specific, which means that a farmer can choose the content and amount of nutrients to meet the specific needs of the plants.

**Where Do Chemical Fertilizers Come From?**

Both phosphorous and potassium are mined from the earth. But they are not available everywhere around the world. In fact, 90% of phosphorous reserves are found in just five countries: China, Jordan, Morocco, South Africa, and the United States (Rosmarin, de Brujine & Caldwell, 2009). And only 12 countries extract and export potassium (The Fertilizer Institute, 2008).

Nitrogen is produced by capturing the nitrogen from the air using a complex chemical reaction. A lot of energy is needed to carry out this chemical reaction. China, India, Russia, and the USA are the leading countries that produce nitrogen-based fertilizers (The Fertilizer Institute, 2008).

Fecal sludge cannot completely replace chemical fertilizers. Annually, about 130 million of chemical fertilizers are sold globally. Of this amount, 78 million tonnes are nitrogen and 13.7 million tonnes are phosphorous. The excreta from 6 billion people contains 27 million tonnes of nitrogen and 3 million tonnes of phosphorous. So in theory, about 35% of the nitrogen fertilizer could be replaced by nitrogen from excreta. Similarly, 22% of the mined phosphorous could be replaced by phosphorous from excreta (WHO, 2006).

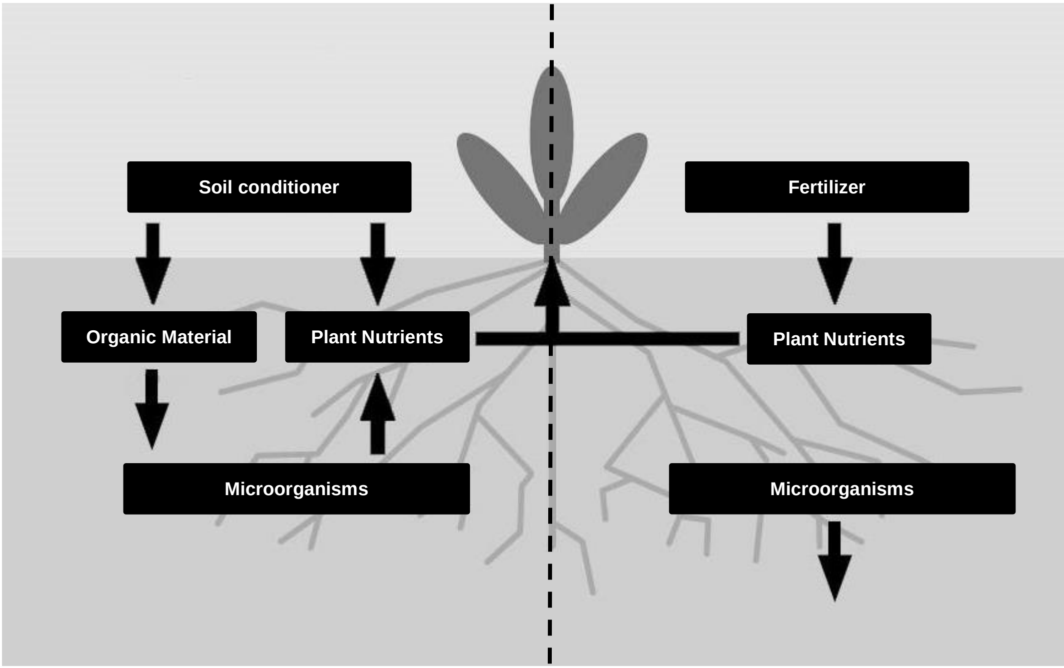
## 3.2 Soil Conditioners

Farmers often focus on using fertilizers to increase crop growth. However, adding soil conditioners, particularly organic material, can be just as important. Soil conditioners improve the physical soil structure by increasing the amount of pore space or making the soil less compact. This extra space increases air and water movement in the soil and allows better root growth.

Soil conditioners can improve the soil's ability to hold water. Just like any other living thing, plants also need water. Plants get their water from the soil. The soil acts like a sponge and absorbs and retains the water. However, certain soils do not hold water as well as others. This is often due to poor agricultural practices that deplete the soil of organic material.

The importance of having enough organic material in the soil includes the following:

- Provides a habitat for microorganisms; they keep the soil loose and make nutrients available for plants
- Regulates water, pH, temperature, and nutrients
- Reduces crusting at the soil surface
- Reduces pests and plant diseases
- Neutralizes toxins and heavy metals




The importance of soil conditioner in addition to fertilizer (Adapted from Soil Atlas, 2015)

## 4 Irrigation

Effluent from on-site sanitation technologies and faecal sludge treatment technologies can be used in irrigation. Effluent, also known as leachate, is the general name for a liquid that is produced by an on-site sanitation technology, like a septic tank. Effluent can also be produced from fecal sludge treatment technologies. Effluent is typically high in nitrogen and pathogens. It may also contain other nutrients, heavy metals, and salts (Strande et al., 2014).

As the world population continues to grow and water scarcity increases, there is more awareness on water conservation. Treated effluent can be used to irrigate home gardens or agricultural crops. This can help communities to grow more food, while at the same time conserve precious water. Effluent should be treated before it is used to reduce the risk of transmitting pathogens.

**Watch the Salt!**

Using effluent for irrigation will increase the salinity of the soil over the long-term. Salt can interfere with plant growth and have long-term impacts on the soil. It is recommended that salinity control practices are used, like making sure that there is enough drainage.

(Strande, Ronteltap & Brdjanovic, 2014; WHO, 2006)

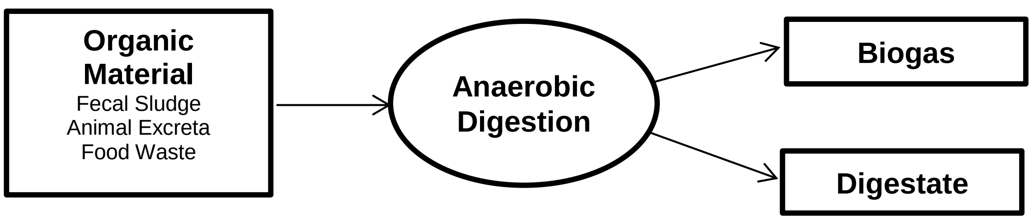
Effluent treatment technologies include waste stabilization ponds, anaerobic baffled reactors, constructed wetlands (also called planted gravel filters), planted drying beds, and anaerobic filters. Effluent can be treated with or without wastewater.

For more information about effluent management see CAWST's Technical Brief: Effluent Management. Also, see CAWST and Eawag-Sandec's Treatment Technology Fact Sheet: Co-Treatment with Wastewater.

## 5 Energy – Biogas

Biogas is produced when microorganisms eat organic material in an environment with no oxygen (called anaerobic). These microorganisms are called anaerobic microorganisms and the process is called anaerobic digestion.

Biogas is made of 60% methane ($CH_4$) and 40% carbon dioxide ($CO_2$). The material that is left after the microorganisms have eaten most of the organic material is called digestate (also called slurry). It contains a lot of nutrients and can be used as a fertilizer if further treated. Think of the human stomach to understand the anaerobic process. We eat food (organic material) that enters our stomach. There is no oxygen in our stomach. After we digest our food we produce both gas and excreta.



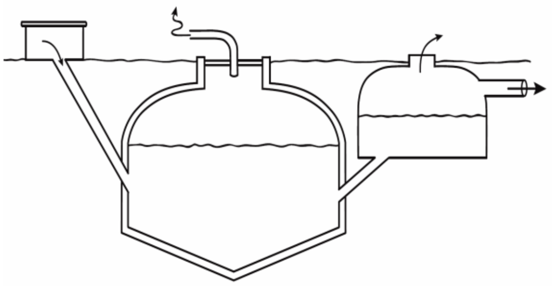
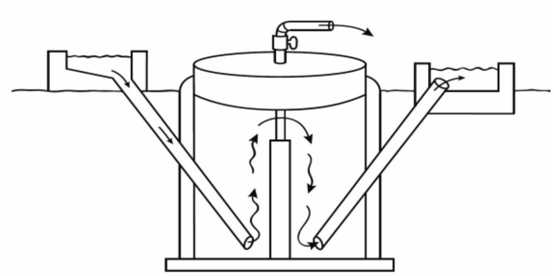

Products of anaerobic digestion

Anaerobic digesters (also called biogas digesters or reactors) have been built all over the world. Countries with extensive programs include China, India, Kenya, Nepal, Sri Lanka, and various countries in Latin America. China is a leader in biogas production with over 7.5 million household anaerobic digesters as well as 750 larger scale production facilities (Bates, 2007).

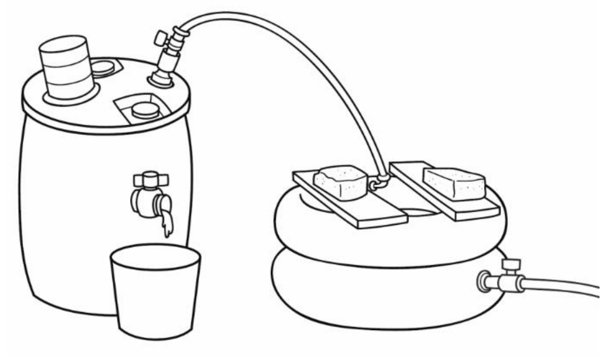
An anaerobic digester is made of an inlet pipe, an outlet pipe, a biogas tank, a collecting tank, and a biogas pipe. Fecal sludge, along with other organic material like animal excreta and food waste, is dumped in the inlet pipe and transported to the digestion tank. Biogas forms in the mixture and rises to the top of the tank. The biogas then flows out through a pipe. There is usually a valve on the pipe that can be opened and closed when gas is needed. As pressure increases, digestate is pushed into the collecting tank, which has an access door to remove the digestate. For more information on the design, operation and maintenance, see CAWST and Eawag-Sandec's Treatment Technology Fact Sheet: Anaerobic Digester.

There are generally two types of anaerobic digesters: the fixed dome (also known as the Chinese reactor) and the floating dome (also known as the Indian reactor). The following table compares the different designs.

**Table: Common Biogas Reactor Designs**

| Fixed Dome | Floating Dome |
|---|---|
| The volume, or space available, does not change and pressure builds up. The more gas produced, the higher the pressure in the tank. The fixed dome reactor is common for households and small-scale use. | The dome on top of the tank floats up and down depending on the volume of gas in the tank. If the volume of gas increases, the dome is pushed up. If gas is used, the dome will descend. |
|  |  |

More designs for simple household anaerobic digesters are being tested and developed. Many are made with local materials like plastic barrels and pipes, like the one shown in the following figure. Minimal tools and skills are required to make them.

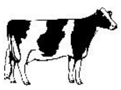


Simple anaerobic digester design

To produce a significant volume of biogas, fecal sludge needs to be mixed with food waste and animal excreta. Anaerobic microorganisms like different types of waste. They will quickly digest the waste they really like. If they don't particularly like a type of waste, they will eat it a lot slower.

**How Much Biogas Can a Household Produce?**

One person's excreta (0.4 kg) produces about 20 litres of biogas per day (NWP, 2006). One person needs about 300–900 litres of biogas per day to cook all of their meals (ISAT & GTZ, 1999).



1 kg cattle excreta produces 40 litres of biogas (Mang, 2005). Cattle produce about 30 kilograms of excreta each day, producing 1,200 litres of biogas (Statistics Canada, 2015).

A household will not produce enough biogas just using human excreta. However, a household with one cow could produce enough biogas needed for their daily cooking.

Microorganisms also have preferences for excreta. As shown in the following table, they like chicken excreta more than human and cattle excreta. Microorganisms also prefer different types of human excreta. For example, they do not particularly like old human excreta from ventilated improved pit (VIP) latrines. The excreta from a VIP latrine is often fairly stabilized (Bakare, 2014). This means that there the organic material has already been broken down. Therefore, the anaerobic digester will not produce much biogas if it is only fed stabilized sludge.

**Table: Biogas Production of Human and Animal Excreta**

| 1 kg of Excreta | Litres of Biogas Produced |
|---|---|
| Human | 50 |
| Cattle | 40 |
| Chicken | 70 |

(NWP, 2006)

## 6 Energy – Solid Fuel

Using fecal sludge to make solid fuel is increasing as an alternative to common fuel sources like wood and charcoal. As common fuel prices increase, there is more interest in new fuel sources, such as fecal sludge. As well, there are less pathogen transmission routes using sludge as a fuel than using it for agriculture. It is, therefore, not subject to strict regulations.

People have made fuel briquettes, pellets and cakes using various waste products, like animal excreta. However, using fecal sludge to make solid fuel is a relatively new science.

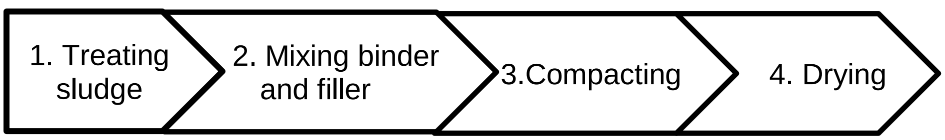
Fecal sludge produces similar energy to wood and charcoal (Niang, Seck, Diene, Gold & Strande, 2015). The heating ability of a material is expressed in calorific value. The unit for this measurement is joules per kilogram of dry material. As shown in the following table, dry fecal sludge can produce more heat than wood and it is within the same range as charcoal.

**Table: Calorific Value of Various Solid Fuels**

| Material | Calorific Value (Megajoules per kilogram of dry material) |
|---|---|
| Straw and hay | 16 |
| Charcoal | 8–32 |
| Wood | 14–18.8 |
| Dry fecal sludge | 22 |

(Niang et al., 2015)

There are four stages to produce briquettes: (1) treating the fecal sludge, (2) mixing binder and filler with the sludge, (3) compacting the material, and (4) drying the briquettes.




Four stages to produce fuel briquettes

The sludge needs to first be treated to reduce the water content and pathogens. This is usually done by increasing the temperature of the sludge. Sanivation, an organization based in Kenya, is using solar energy to heat the fecal sludge and kill the pathogens (Sanivation, 2015). Dried feces can also be carbonized using a kiln to reduce the smoke released by the briquette and ensure all pathogens are inactivated. Carbonization is when fecal sludge is heated to high temperatures in the absence of oxygen. The material is not turned to ash, but breaks down. The end products are char, oils, and gases (Lohri, Sweeney & Rajabu, 2015).

The dried sludge then needs to be mixed with a binding agent to hold the briquette together (Village Volunteers, n.d.). You need some moisture to mix all the components together. The binding material is a fibrous organic material. It should be cheap and locally available year round. Materials with a lot of starch have proved to be very effective, such as corn, wheat, and certain vegetable peels (Nyer, 2012). They use waste from the flower industries as the main component of their briquettes.

Depending on fecal sludge characteristics and the treatment method, the sludge may also need to be mixed with a filler. The filler makes it easier to maintain a flame. Examples of fillers are sawdust, coffee husks, coffee pulps, or even charcoal fines. The mixed materials are then formed into briquette shapes using a press and dried. The final briquettes should have a dryness of 90% to burn most efficiently (Gold et al., 2014).

# 7 Livestock

## 7.1 Animal Protein

Fecal sludge can also be fed to high-protein animals, like black soldier fly larvae, to then feed farm animals, such as chickens. Farmers use a lot of their budget to feed their animals. They commonly buy soybeans, canola, cereal by-products, meat and bone as well as fish to provide protein for their animals. However, new animal feeds are being tested to be cheaper and more efficient than the common animal feeds.

Using black soldier fly larvae is a fairly new and simple approach to animal feed. Farmers place the fly larvae inside a bin. They feed the larvae excreta and other organic waste. The larvae grow as they eat the excreta and organic waste. This growing period can vary between 2–8 weeks, depending on the amount of food they are fed and the climate (Warkomski, 2015). Before the larvae become adult flies, they are collected and fed to farm animals. There is little research on the risk of disease transmission by feeding the larvae to animals. Recent research showed certain pathogens, such as *Enterococcus* and *Ascaris*, are not inactivated through this process (Lalander et al., 2013). Farmers should therefore treat the fecal sludge before feeding it to the larvae.

See CAWST and Eawag-Sandec's Treatment Technology Fact Sheet: Black Solider Fly for more information.

**Aren't Black Soldier Flies a Vector?**

Flies are usually a vector for spreading diseases. However, the black soldier fly has an advantage. It does not eat once it is adult size and can fly. In fact, it has no mouth. These flies are not attracted to feces or food. They are, therefore, not a vector.

## 7.2 Plants

Fecal sludge can also be treated using a planted drying bed to produce plants for animal feed. Plants are carefully chosen for the climate and to grow under the conditions in the drying bed (Strande, et al., 2014). The most frequently used plant is one type of reed called *Phragmites australis* (De Maeseneer, 1997; Hardej and Ozimek, 2002). Harvesting the plants happens when the technology is desludged and plants are cut at the surface of the drying bed (Strande, et al., 2014).

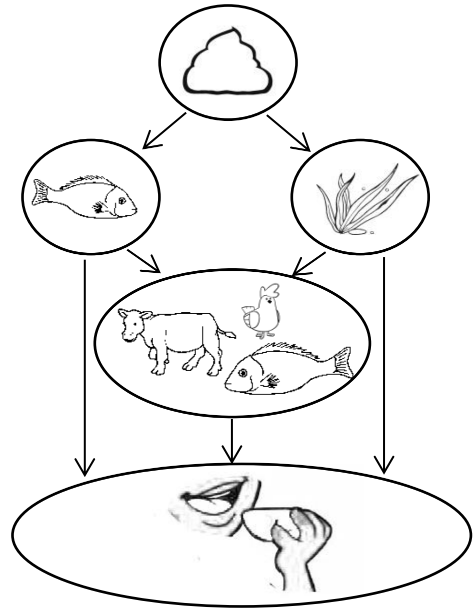
See CAWST and Eawag-Sandec's Treatment Technology Fact Sheet: Planted Drying Bed for more information.

## 8 Aquaculture

Fecal sludge can also be fed to aquatic organisms such as fish (for example, carp) and aquatic plants (for example, water mimosa, water spinach, watercress, water chestnut and duckweed). Aquaculture is usually for human consumption, but some aquatic plants and fish can be fed to other fish or livestock.

Aquaculture is an old tradition, particularly used in Asia still to this day. Aquatic plants are an important part of the diet in Southeast Asia and is important for food security (WHO, 2006b).

Aquaculture can be intentional or unintentional. Unintentional aquaculture is more common around the world. It occurs when there is illegal dumping of wastewater or fecal sludge in a water body. This can be in a lake, river, small pond or in the ocean. Farmers cage the fish and install stakes to grow plants in these water bodies. This makes it easier for them to catch the fish and harvest the aquatic plants.



Aquaculture food chain

Fecal sludge used for aquaculture should be treated first. Therefore, overhanging toilets are not recommended. These are toilets built above the water and the excreta falls directly into the water. This practice is quite common in Southeast Asia.

See CAWST and Eawag-Sandec’s Treatment Technology Fact Sheets: Fish Pond and Floating Plant Pond for more information.

**The Art of Aquaculture**

Some call aquaculture an art form more than a science. It is very difficult to maintain optimal conditions for aquaculture. A water body can quickly accumulate too much organic material or nutrients which damages the aquatic ecosystem. There is also very little scientific information on aquaculture.

## 9 Building Materials

Dried fecal sludge can be used to make cement and bricks, and to produce clay-based materials. Dried fecal sludge has been shown to have similar qualities as other building materials, like limestone and clay materials.

In Japan, dried fecal sludge is commonly used as an alternative fuel in the kiln to produce cement. The ash from incinerating fecal sludge is also incorporated into the cement (Strande, et al., 2014).

Bricks made from dried fecal sludge

Pathogen transmission is less of a concern when fecal sludge is used as a building material since human contact is reduced. As well, the pathogens are killed by high temperatures during the manufacturing process.

## 10 Risk Reduction

People can potentially get sick when using fecal sludge through different transmission routes, such as:

- Direct contact when handling fecal sludge
- Contact with soil contaminated with fecal pathogens. This is particularly important in agriculture and areas where *Ascaris lumbricoides* (a type of roundworm) is present.
- Contact with water contaminated with fecal pathogens. This is particularly important in aquaculture and areas where schistosomiasis is present.
- Eating food or drinking water contaminated with fecal pathogens.

For more information on *Ascaris,* schistosomiasis and other fecal pathogens, see CAWST's Technical Brief: What is Fecal Sludge?

Fecal sludge should be treated first to inactivate pathogens before it is used. However, it can be difficult to treat and monitor fecal sludge to ensure that it is safe to use. See CAWST's Technical Brief: Fecal Sludge Treatment and Technical Brief: Fecal Sludge Treatment Mechanisms for more information.

As such, several barriers can be put in place after treatment to minimize the risk of transmitting fecal pathogens while it is being used. These barriers focus on protecting the people handling the fecal sludge (like farmers), those eating the food or using the product (consumers), and the local community. This is often known as a multi-barrier approach to prevent or eliminate a sanitation-related risk, or reduce it to an acceptable level (WHO, 2016).

**Table: Barriers to Protect Health**

| **Barriers to Protect Health** | | **Action** |
|---|---|---|
|  | Crop restriction | Only use treated faecal sludge for crops that:<br>• Are not eaten (like cotton)<br>• Are processed (like wheat)<br>• Are cooked (like potatoes)<br>• Do not directly touch the ground (like bananas) |
|  | Application techniques | Mix treated faecal sludge into the soil and then cover with soil. Do not apply directly on the plant. |
|  | Use protective equipment | Wear protective equipment, such as clothing, gloves, shoes, and mask. |
|  | Waiting period | Wait one month after applying the fecal sludge before harvesting crops. Pathogens continue to be inactivated once they are in the soil. Inactivation is much faster in hot and sunny climates than cold and rainy climates. |

| Barriers to Protect Health | | Action |
|---|---|---|
|  | Prepare food properly | Wash fruits and vegetables with safe water before eating. Wash hands with soap before cleaning and preparing food. Cook all food thoroughly and do not eat raw food. |
|  | Wash hands | Wash hands with soap after handling fecal sludge, tools, and equipment. |
|  | Clean tools | Disinfect the tools used to handle fecal sludge, and only use them for this activity. Safely store the tools so people do not touch them or use them for another purpose. |
|  | Train | Train sanitation service providers, farmers, families, and the community on best fecal sludge management and hygiene practices. |
|  | Deworm | Provide treatment for helminth infections to sanitation service providers, farmers, and their families. This will help to break the transmission cycle and reduce helminths in excreta. |

As well, the World Health Organization (WHO) has developed the Guidelines for Safe Use of Wastewater, Excreta and Greywater in 2006. They provide a comprehensive framework for managing health risks associated with using human waste in agriculture and aquaculture.

**Case Study: Hanam, Vietnam**

A study was conducted in the community of Hanam, Vietnam to assess the relationship between agricultural use of excreta/wastewater and diarrhea. Over one year, diarrhea incidences were monitored for adults without direct contact to excreta/wastewater and adults with direct contact. The study concluded that adults with direct contact had a higher incidence of diarrhea. Some of the risk factors identified were:

1. Using no protective measures
2. Composting human excreta for less than three months
3. Never washing hands with soap

(Pham-Duc et al., 2014)

## 11 Knowledge Gap

Knowledge on how to use fecal sludge safely is limited. The main gaps are the following:

- There is a limited research on the health risks of using fecal sludge. It has led governments to set unrealistic targets or avoid creating standards at all. Most countries, for example, do not have standards for using fecal sludge in agriculture (Johansson & Kvarnstrom, 2005). Standards for using wastewater in agriculture are more likely to exist because there is more research on wastewater than fecal sludge.

- Other than using feces and urine for agriculture, other innovative uses are in experimental stages or being tested at a pilot or small-scale. More research is needed to improve these new technologies, particularly in terms of cost and sustainability.
- There is limited research on the effects of trace organics (such as natural hormones, synthetic hormones, and pharmaceuticals) in fecal sludge on the environment and public health. Researchers have only recently begun to study whether and how trace organics affect living things in the environment and what this means for public health.

## 12 Definitions

This section includes key definitions in this Technical Brief. For a complete list of sanitation terms and definitions see CAWST's Guide to Sanitation Resources or http://www.cawst.org/WASHglossary.

**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.

**Anaerobic digester**: Also called a biogas digester or biogas reactor. A technology that uses the process of anaerobic digestion to produce biogas.

**Chemical fertilizer:** Also called artificial, synthetic or commercial fertilizers. A material produced by industry containing nutrients that plants need to grow.

**Ecological sanitation:** Also called ecosanitation, ecosan, resources-oriented sanitation or productive sanitation. An approach that aims to safely recycle nutrients, water and energy from excreta and wastewater. This is done in a way that minimizes the use of non-renewable resources.

**Effluent:** Also called leachate. Liquid that is produced from an on-site sanitation technology (like a septic tank) or fecal sludge treatment technology.

**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.

**Risk:** The likelihood of a hazard causing harm to exposed populations in a specific time frame and the consequences of that harm.

**Soil amendment:** Anything mixed into soil to improve soil quality and support healthy plant growth. Fertilizers and soil conditioners are two types of soil amendments. Fertilizers add nutrients to the soil that plants need to grow. Soil conditioners improve the physical soil structure.

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

## 13 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.

**EcoSanRes Series.** Available at: www.ecosanres.org/publications.htm

- EcoSanRes was a five-year program that developed evidence-based publications on ecological sanitation. The program focused on capacity building and knowledge management.

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

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

**Guidelines for Safe Use of Wastewater, Excreta and Greywater.** WHO (2006). Geneva, Switzerland: World Health Organization. Available at: www.who.int/water_sanitation_health/wastewater/gsuww/en/

- The Guidelines provide a comprehensive framework for managing health risks associated with using human waste in agriculture and aquaculture. They were designed to assist in developing national and international approaches (like policies and legislation), and to provide a framework for national and local decision making to identify and manage health risks.

## 14 References

Bakare, B. F. (2014). *Scientific and management support for ventilated improved pit latrines sludge content*. University of KwaZulu Natal, South Africa. Retrieved from www.susana.org/en/resources/library/details/1945

Bates, L. (2007). Technical brief: Biogas. Practical Action. Retrieved from http://sustainnovate.ae/resources/files/Technical_brief_-_biogas.pdf

De Maeseneer, J.L. (1997). Constructed wetlands for sludge dewatering. *Water Science and Technology*, 35(5), 279-285.

Fields, S. (2004). Global nitrogen: Cycling out of control. *Environ Health Perspect.* 2004 Jul; 112(10): A556–A563. Retrieved from www.ncbi.nlm.nih.gov/pmc/articles/PMC1247398/

Gold, M., Niang, S., Niwagaba, C. B., Eder, G., Murray Muspratt, A., Diop, P. & Strande, L. (2014). Results from FaME (Faecal Management Enterprises - Can dried faecal sludge fuel the sanitation service chain? 37th WEDC International Conference. Retrieved from http://wedc.lboro.ac.uk/resources/conference/37/Gold-2026.pdf

Hardej, M., Ozimek, T. (2002). The effect of sewage sludge flooding on growth and morphometric parameters of Phragmites australis (Cav.) Trin. ex Steudel. Ecological Engineering, 18(3), 343-350.

ISAT & GTZ. (1999). Biogas Digest. Retrieved from http://www.sswm.info/sites/default/files/reference_attachments/ISAT%20GTZ%201999%20Biogas%20digest%20Volume%20I%20Biogas%20Basics.pdf

Johansson, M. & Kvarnstrom, E. (2005). *A review of sanitation regulatory frameworks* (No. 2005-1) (p. 60). Sweden: Stockholm Environment Institute. Retrieved from http://www.ecosanres.org/pdf_files/ESR_publications_2005/ESR_2005-1.pdf

Lalander, C., Diener, S., Magri, E. M., Zurbrügg, C., Lindstrom, A. & Vinneras, B. (2013). Faecal sludge management with the larvae of the black soldier fly (Hermetia illucens) — From a hygiene aspect. *Science of the Total Environment*, *458-460*, 312–318. http://doi.org/10.1016/j.scitotenv.2013.04.033

Lohri, C. R., Sweeney, D. & Rajabu, H. M. (2015). *Carbonizing urban biowaste for low-cost char production in developing countires. A review of knowledge, practices and technologies*. Joint Report by: EAWAG, MIT D-Lab and UDSM. Retrieved from www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/Carbonization_of_Urban_Bio-waste/Carbonization_of_Biowaste_in_DCs_FINALx.pdf

Mang, H.-P. (2005). *Biogas sanitation systems*. Beijing: Chinese Academy of Agricultural Engineering. Retrieved from http://www.sswm.info/sites/default/files/reference_attachments/MANG%202005%20Biogas%20Sanitation%20Systems.pdf

Niang, S., Seck, A., Diene, A., Gold, M. & Strande, L. (2015). *Converting faecal sludge to fuel: A new management solution*. Hanoi, Vietnam. Retrieved from www.susana.org/en/resources/conference-materials-2/2015/259-fsm3

NWP. (2006). *Smart sanitation solutions. Examples of innovative, low-cost technologies for toilets, collection, transportation, treatment and use of sanitation products.* Amsterdam, Netherlands: NWP. Retrieved from www.sswm.info/sites/default/files/reference_attachments/NWP%202006%20Smart%20Sanitation%20Solution.pdf

Nyer, B. (2012). Fuel briquette materials assessment. University of Colorado, USA. Retrieved from http://mcedc.colorado.edu/sites/default/files/Briquette%20Material%20Assessment%20-%2003252012_0.pdf

Pham-Duc, P., Nguyen-Viet, H., Hattendorf, J., Dac Cam, P., Zurbrügg, C., Zinsstag, J. & Odermatt, P. (2014). Diarrhoeal diseases among adult population in an agricultural community Hanam province, Vietnam, with high wastewater and excreta re-use. *BMC Public Health*, *14*(978). http://doi.org/10.1186/1471-2458-14-978

Rosmarin, A., de Brujine, G. & Caldwell, I. (2009). The next inconvenient truth: Peak phosphorus. *The Broker*, (15), 6-9. Retrieved from http://www.thebrokeronline.eu/Articles/Peak-phosphorus

Sanivation. (2015).
Retrieved from http://sanivation.com/

Soil Atlas. (2015). *Soil atlas: Facts and figures about earth, land and fields*. Heinrich Boll Foundation and Institute for Advanced Sustainability Studies. Retrieved from http://globalsoilweek.org/wp-content/uploads/2014/12/soilatlas2015_web_141221.pdf

Statistics Canada. (2015). *A geographical profile of livestock manure production in Canada, 200*6. Retrieved from http://www.statcan.gc.ca/pub/16-002-x/2008004/article/10751-eng.htm#a3

The Fertilizer Institute. (2008). Fertilizer's role in world food production. Retrieved from https://www.tfi.org/

Village Volunteers. (n.d.). A trainer's guide for making fuel briquette. Legacy Foundation. Retrieved from https://www.villagevolunteers.org/wp-content/uploads/2011/06/Fuel-Briquettes-Guide.pdf

Warkomski, K. (2015). *Black soldier fly production*. Living Web Farms. Retrieved from www.livingwebfarms.org/black-soldier-fly-production/4587532790

WHO. (2006). *Guidelines for the safe use of wastewater, excreta and greywate*r. Geneva, Switzerland: World Health Organization. Retrieved from www.who.int/water_sanitation_health/wastewater/gsuww/en/

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

Compendium images can be retrieved at: www.eawag.ch/en/department/sandec/publications/compendium/

---

CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Canada
Website: www.cawst.org Email: support@cawst.org
*Wellness through Water.... Empowering People Globally*
Last Update: July 2016

---

This document is open content. You are free to:

- Share – Copy and redistribute the material in any medium or format
- Adapt – Remix, transform, and build upon the material for any purpose, even commercially

Under the following terms:

- Attribution – You must give appropriate credit to CAWST, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests that CAWST endorses you or your use. Please include our website: www.cawst.org

CAWST and its directors, employees, contractors, and volunteers do not assume any responsibility for, and make no warranty with respect to, the results that may be obtained from the use of the information provided.