Technical Brief: Fecal Sludge Treatment – Pathogen Inactivation Mechanisms

Sanitation System

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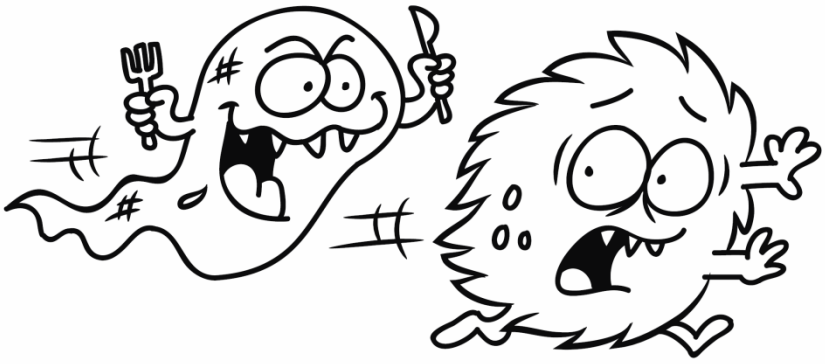

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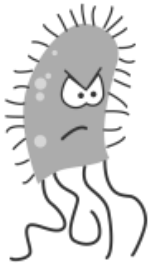
1 Introduction



Fecal sludge naturally contains many living things. Some are harmless or even beneficial, but others can cause illness. Living things that cause disease are also known as **pathogens**. They are sometimes called other names, such as organisms, microorganisms, microbes or bugs, depending on the local language and country. There are four different categories of pathogens: bacteria, protozoa, viruses, and helminths (worms).

Pathogens can be inactivated (also called reduced) in fecal sludge using different physical, chemical, and biological treatment mechanisms. These include time, temperature, moisture, pH, and solar radiation. This Technical Brief explains how these different ways (also called mechanisms) inactivate pathogens.

Knowing the different ways that pathogens can be killed is helpful to understand how treatment technologies work. As well, understanding pathogen inactivation helps to monitor the safety of treated fecal sludge.

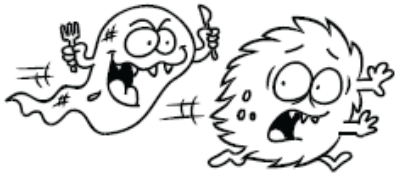
For more information on the different treatment technologies, see CAWST's Technical Brief: Sanitation System – Fecal Sludge Treatment and CAWST Eawag-Sandec Treatment Technology Fact Sheets.

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 Time

The number of pathogens in fecal sludge will decrease over time. Inside the human body, pathogens enjoy optimal conditions to survive and multiply. However, once they are excreted from our bodies, the conditions are not as good. For example, the temperature changes, food might not be as available, and they may have predators. Pathogens in fecal sludge will be eaten by other microorganisms, starve, or naturally die-off over time.



Sometimes the environmental conditions are favourable for the pathogens to survive. In certain conditions, pathogens can survive for a long time and some can even reproduce. Some pathogens, like *Ascaris lumbricoides* (roundworm) eggs, can remain viable for years because of their impermeable eggshell (Strande, Ronteltap & Brdjanovic, 2014). Protozoa and viruses can only multiply when they are in a host, like a person or animal.

Many fecal sludge treatment technologies inactive pathogens over time. For more information about these technologies see CAWST and Eawag-Sandec's Treatment Technology Fact Sheets:

- Anaerobic digestion
- Black soldier fly larvae
- Co-composting
- Planted drying bed
- Settling-thickening
- Storage
- Thermal drying
- Deep row entrenchment
- Fish pond
- Plant pond
- Unplanted drying bed
- Vermicomposting
- Vermifilter

3 Temperature

Raised temperatures can kill pathogens. Pathogens have optimal growth temperatures. If it is too hot or too cold, they slow down their activity to survive for a longer time. However, over certain temperatures, molecules that are essential for life are denatured. This means that the structure of the molecule is changed. Denaturation is similar to the physical change in proteins you see when you fry an egg.

For composting, fecal sludge should be kept at temperatures above 50°C for at least one week, to ensure that pathogens are killed to a safe level (WHO, 2006). Most pathogens in fecal sludge will die in less than a day at temperatures between 40-50°C (Feachem, Bradley, Garelick & Mara, 1983). For example, enteric viruses will die at 50°C after one day. The bacteria *Vibrio cholerae* will die at 38°C after one day.

The graph below shows how long it takes to kill pathogens at different temperatures. There are various ways to read this graph:

- You can look at a specific pathogen and read the temperature and time required to inactivate it.
- You can look at a specific temperature and time and read what pathogens are inactivated and which ones remain alive.

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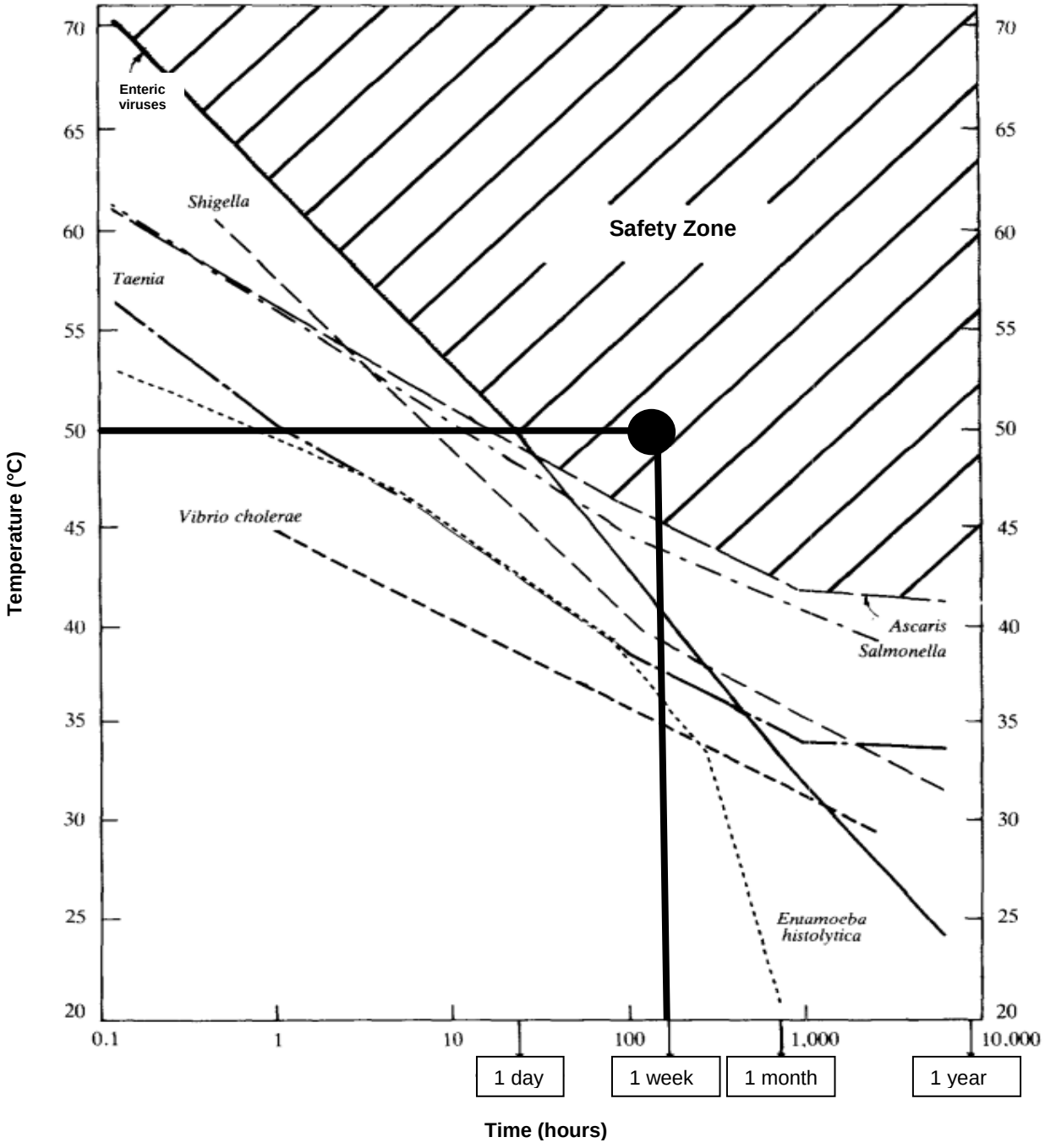
Figure: Pathogen Inactivation in Relation to Temperature and Time



(Feachem et al., 1983)

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It is important to note that high temperatures are difficult to reach naturally, even in hot climates. The temperature of fecal sludge in a pit latrine, for example, is similar to the temperature outside. This means that households and communities need to reach these temperatures using treatment technologies, or design their on-site sanitation technologies to store the sludge for a long time to reduce pathogens. The following table lists the World Health Organization (WHO) recommendations for temperatures and timeframes needed to reduce pathogens.

Table: WHO Temperature and Time Treatment Recommendations

Temperature	Timeframe	Pathogen Reduction
2-20°C	1.5-2 years	• Will eliminate bacteria, although some might be dormant and could be reactivated • Will reduce viruses and protozoa below risk levels • Some helminth eggs may persist
20-35°C	At least 1 year	• Substantial to complete inactivation of viruses, bacteria, and protozoa • Inactivation of helminth eggs within a few months, apart from *Ascaris* eggs that can take longer

(WHO, 2006)

Co-composting is the most commonly used fecal sludge treatment technology to increase temperature. Co-composting is an effective ways to reduce pathogens in fecal sludge, while at the same time producing a valuable resource. During the composting process, microorganisms (such as bacteria, yeast, and worms) break down the organic material in the fecal sludge. This process releases heat and kills pathogens. For more information on co-composting see:

Co-composting fecal sludge in a bin

- CAWST's Technical Brief: Sanitation System – Fecal Sludge Treatment Technologies
- CAWST and Eawag-Sandec Co-Composting Treatment Technology Fact Sheet.

There are other fecal sludge treatment technologies that inactivate pathogens through raised temperature. See CAWST and Eawag-Sandec's Treatment Technology Fact Sheets:

- Incineration
- Thermal drying

Does Anaerobic Digestion Increase Temperature?

Treatment technologies that use anaerobic digestion (like a biogas digester) do not increase the temperature. Anaerobic microorganisms feed on organic material and release a gas called biogas. This reaction does not release heat.

4 Moisture

Just like people, microorganisms need water to survive. As moisture drops to a certain level, pathogens will start to die. Fecal sludge naturally has a high water content, even if no flush water or anal cleansing water is used.

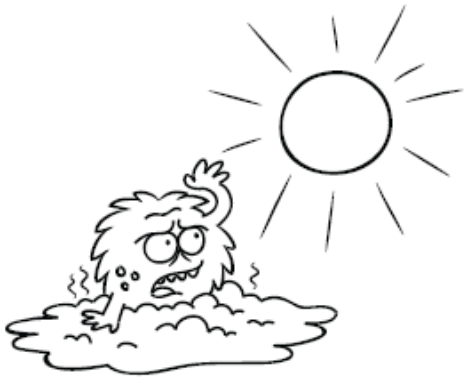
Dewatering removes water from the faecal sludge, mainly through filtration or settling. Drying further removes water through evaporation or using thermal energy (heat). To understand the difference between dewatering and drying, think of a wet towel. You first have to wring the towel (dewatering), then you have to hang your towel to dry (drying).

For more information about fecal sludge treatment technologies that remove moisture, see CAWST and Eawag-Sandec's Treatment Technology Fact Sheets:

- Planted drying bed
- Unplanted drying bed
- Thermal drying

5 Solar Radiation

Sunlight can destroy pathogens with ultraviolet (UV) light and infrared radiation. UV radiation damages and kills living cells. The light rays must reach the pathogens to inactivate them, so this is only effective for pathogens on the surface of the fecal sludge. Infrared radiation heats the sludge to reach temperatures that inactivate pathogens.



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For more information about fecal sludge treatment technologies that remove moisture, see CAWST and Eawag-Sandec's Treatment Technology Fact Sheets about:

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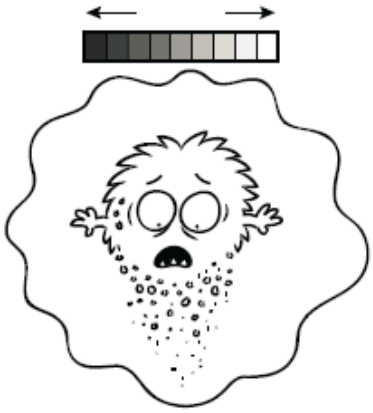
6 pH



The pH is a measure of how acidic or basic (alkaline or caustic) something is. It ranges from pH 0 to 14, with 7 being neutral. A pH less than 7 is acidic and a pH greater than 7 is basic.

Most pathogens can only survive within a range of pH 2 to 3. Also, most pathogens cannot survive below pH 3 or above pH 10 (Strande, Ronteltap & Brdjanovic, 2014). By changing the pH of fecal sludge, pathogens can be inactivated.

The following table shows the WHO recommendations for pH levels needed to reduce pathogens in fecal sludge.

Table: WHO pH Treatment Recommendations

pH	Time	Pathogen Reduction
Above pH 9	At least 6 months	• Inactivation of all pathogens will take longer if the fecal sludge is wet and/or the pH is lower

(WHO, 2006)

It is important to note that changing the pH can also have a negative impact on other biological processes. For example, it can disrupt aerobic and anaerobic digestion for treating fecal sludge.

What Chemicals Can Be Used to Change pH?

The following chemicals are often used to change the pH of domestic wastewater: chlorine, ozone, acids, alkalines (such as lime), and urea.

Based on the experience with domestic wastewater, treating fecal sludge with chemicals is starting to be researched and implemented, in particular using alkalines (lime) and urea. For more information, see CAWST and Eawag-Sandec's Treatment Technology Fact Sheet: Alkaline Treatment.

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7 Additional Resources

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

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

Faecal Sludge Management: Systems Approach for Implementation and Operation. Strande, L., Ronteltap, M. & Brdjanovic, D. (Eds.) (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.

8 References

Feachem, R. G., Bradley, D. J., Garelick, H. & Mara, D. D. (1983). *Sanitation and disease: Health aspects of excreta and wastewater management*. Washington DC, USA: John Wiley & Sons for World Bank. Retrieved from http://documents.worldbank.org/curated/en/1983/01/439534/sanitation-disease-health-aspects-excreta-wastewater-management

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