Chapter 2.1

Treatment objectives

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Learning objectives

- Name different treatment objectives
- Relate health and environmental impacts to treatment objectives
- Understand different levels of appropriate treatment depending on enduse

Textbook

Available at www.sandec.ch/fsm_book

- Strande, L., Ronteltap, M. and Brdjanovic, D. (2014). *Faecal Sludge Management - Systems Approach for Implementation and Operation*.

Free online courses (MOOCs)

Available at www.eawag.ch/mooc

- *Introduction to Faecal Sludge Management.* MOOC series by Eawag and EPFL. Module 'Treatment Objectives'.
- *Planning & design of sanitation systems and technologies*. MOOC series by Eawag and EPFL. Week ´Introduction to sanitation planning & systems approach´.

Further Eawag-Sandec publications

- Tilley, E., Ulrich, L., Lüthi, C., Reymond, P. and Zurbrügg, C. (2014). *Compendium of Sanitation Systems and Technologies. 2nd edition.* Dübendorf, Switzerland, Swiss Federal Institute of Aquatic Science and Technology (Eawag). www.sandec.ch/compendium

Additional resources

- Metcalf & Eddy (2014). *Wastewater Engineering: Treatment and Resource Recovery.* 5th Edition, McGraw-Hill, New York.
- Tayler, K. (2018). *Faecal sludge and septage treatment – a guide for low and middle income countries.* Rugby, UK, Practical Action Publishing.
- Von Sperling, M. and De Lemos Chernicharo Augustos, C. (2005). *Biological Wastewater Treatment in Warm Climate Regions.*
- World Health Organisation (2015). *Sanitation safety planning manual for safe use and disposal of wastewater, greywater and excreta.* Switzerland.
- World Health Organization (2018). *Guidelines on sanitation and health.* Licence: CC BY-NC-SA 3.0 IGO.

Introduction

The main goal of sanitary engineering and faecal sludge management is the protection of public health. The 'f' diagram below depicts faecal-oral routes of contamination, which need to be prevented to reduce health risks and protect public health. The pathways are represented by the 'f' words: faeces, fluids, fields, flies, food and fingers, as shown in Figure 2.1.1. Protection of environmental health is also an important goal, which is closely linked to the protection of public health. Safe disposal is also a goal, and whenever possible resource recovery should be considered, which is covered in more detail in chapter 2.3.

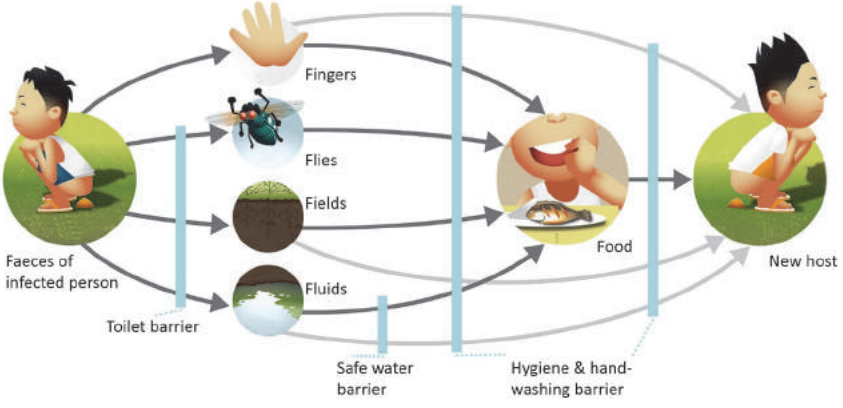

Figure 2.1.1 The 'f' diagram illustrating the infectious transmission pathways of pathogens (adapted from wikipedia.org).

The above mentioned goals can be translated into four main treatment objectives for faecal sludge: dewatering, stabilization, nutrient management, and pathogen inactivation.

Dewatering is important, as faecal sludge is typically over 90% water, and water is cumbersome and expensive to transport. Large volumes of contaminated water can also easily contaminate the environment, so separation of liquids and solids is also important for more effective treatment options.

Stabilization is the process of converting biodegradable organic matter into more stable complex molecules. This is important for treatment, as readily degradable matter consumes significant amounts of oxygen during degradation. If it is directly discharged this can cause environmental damage. For example, in a river it will result in a rapid drop in the dissolved oxygen in the water, which will create anaerobic conditions that can kill the aquatic organisms. Stabilization also results in nutrient stabilization, as ionic forms are taken up into the organic matter, meaning they are not readily leached out and available for plant growth. Stabilization normally also results in a reduction of the odour.

The nutrient management aspect is important to preserve beneficial nutrients for resource recovery options, and to prevent environmental contamination. As mentioned, stabilization is also important for nutrient management. Environmental impacts from nutrients include eutrophication and algal blooms in surface waters, and contamination of drinking water. Moreover, nutrients are of relevance for resource recovery in agriculture.

As illustrated by the 'f' diagram, pathogen inactivation is important to prevent direct contact or indirect exposure to pathogens. The appropriate level of pathogen inactivation during treatment processes will depend on the intended enduse, and on possible routes of exposure. The treatment objectives should not be prioritized; however, pathogen inactivation is crucial for the protection of public health. There are seven mechanisms for pathogen inactivation that occur during treatment; age, predation, starvation, temperature, moisture, pH, and solar radiation or ultraviolet light; refer to chapter 2.2 for more information about how to inactivate pathogens.

The transmission cycle of pathogens can be interrupted by putting barriers in place to block transmission paths and prevent cycle completion. The first barrier for beneficial use is provided by the level of pathogen inactivation achieved through the treatment of faecal sludge. A selection of further post-treatment barriers, prior reusing treated solid and liquid streams, may include:

- restriction of use on crops that are eaten raw,
- withholding periods between application and harvest to allow pathogen die-off,
- drip or subsurface irrigation methods,
- restricting worker and public access during application,
- use of personal protective equipment,
- safe food preparation methods such as thorough cooking, washing or peeling.

When considering the risk of infection, all the potential exposure groups should be accounted for which can be broadly categorized as workers and their families, the surrounding communities and the product consumers. For more information on a multi-barrier risk-based approach to ensure adequate protection of public health, refer to the new WHO Guidelines on Sanitation and Health (2018), the Sanitation safety planning manual for safe use and disposal of wastewater, greywater and excreta (2015), and the Sanitation Safety Planning Module in Sandec's MOOC on Planning & design of sanitation systems and technologies.

Example 2.1.1 When national guidelines are not available

World Health Organization. (2018). *Guidelines on sanitation and health.*

The importance of faecal sludge management is rapidly gaining worldwide acknowledgement. However, in many locations, policies and guidelines are not yet in place. Therefore, the World Health Organisation has developed guidelines that can be used by national and local authorities as a starting point when building their own guidelines, to ensure adequate treatment objectives are defined, regulated and enforced. These guidelines

can also be used as treatment objectives by practitioners when designing for management and treatment solutions in the absence of other standards.

The purpose of the guidelines is to protect public health by promoting safe sanitation systems and practices. They seek to support authorities and practitioners to identify health risks and ways to manage them effectively.

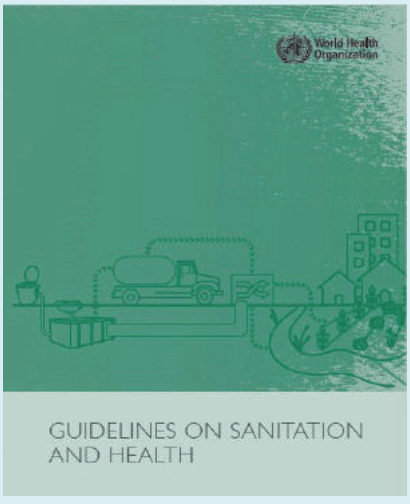

Figure 2.1.2 ***Guidelines on sanitation and health.*** **World Health Organization (2018).**

Example 2.1.2 Setting treatment objectives based on intended resource recovery

In the absence of regulations, a way to establish treatment objectives is to set them specifically for the intended resource recovery option. See chapter 1.2 for more details about the engineering design approach. The appropriate level of treatment will depend on the resource recovery or disposal option. For example, if faecal sludge is to be used as a fuel in combustion, the number one objective is dewatering to increase the fuel potential. In this case, lower levels of pathogen inactivation are acceptable (if protective measures for handling exist) as the faecal sludge will be incinerated. If faecal sludge is to be composted, and used for food crop production, pathogen reduction is the main goal. The treatment objective should always be linked with the enduse to ensure the protection of public and environmental health. This thinking also applies similarly to all of the four treatment objectives as well as the resource recovery options.

Exercises

1. Adequate sanitation services can help prevent the transmission of pathogens. By identifying the faecal-oral transmission pathways public health can be protected. Use the 'f' diagram above and explain the routes of contamination for each of the 'f' words.
2. Explain stabilization as a treatment objective. State whether stabilized or unstabilized faecal sludge is wanted for agricultural use and energy use, respectively.
3. Pathogen inactivation is important to protect public health. How does storage kill pathogens? (hint: pathogen inactivation mechanisms)
4. What would be different in your approach to nutrient management if the faecal sludge treatment effluent is used for irrigation or if it is disposed of into a surface water body?
5. Stabilization and nutrient management are interlinked. Describe why, and give two nutrients that are relevant to faecal sludge effluent.
6. When faecal sludge management is poorly managed it has a negative impact on the environment, and the public health. Link the potential negative impacts in the list below with the component of the faecal sludge that is responsible for the negative impact. Each bullet point can have more than one component.
   Faecal sludge components; pathogens, organic material, nutrient and water.
   - What makes people sick?
   - What component can increase algae in surface water and lead to the death of aquatic organisms?
   - What makes faecal sludge smell bad?
   - What makes faecal sludge heavy and voluminous to manage?
   - What component increases the risk of water contamination?
   - What component attracts rats and flies?
7. Why do treatment objectives ensure the protection of public and environmental health?
8. Explain how the treatment objectives as a concept contribute to the protection of public health, and to the protection of environmental health.
9. In the absence of regulations for the treatment of faecal sludge, working with the concepts of treatment objectives can be very beneficial. Explain why.
10. Assuming that the intended enduse for treated faecal sludge is to produce pellets to feed an electricity producing gasifier. Discuss the appropriate treatment objective(s).
11. Assuming that the intended enduse for treated faecal sludge is co-compost which will be applied on edible crops. Discuss the appropriate treatment objective(s).
12. Assuming that the intended enduse for treated faecal sludge includes the use of effluent for the irrigation of fruit trees. Discuss the appropriate treatment objective(s).
13. Discuss the importance of dewatering as a treatment objective during faecal sludge treatment.
14. You are the faecal sludge professional of a treatment plant. The water body outside the faecal sludge treatment plant indicates BOD levels over the regulatory limits. These have

led to depletion of oxygen in the surface water. What treatment objective(s) needs to be further enforced and/or evaluated in the faecal sludge treatment modification?

a) Dewatering
b) Stabilization
c) Nutrient management
d) Pathogen inactivation

15. Draw a line to link the events with the treatment objectives. The events can be linked to more than one treatment objective.

Events	Treatment objectives
Cholera outbreak	Dewatering
Increased diarrheal diseases	Stabilization
Fish die off in a lake	Nutrient management
Expensive transport of faecal sludge with high water content	Pathogen inactivation
High nitrate levels in faecal sludge effluent contaminate drinking water sources	

16. Assuming the intended enduse for treated faecal sludge is biochar as cooking fuel. Based on a multi-barrier approach, explain what barriers can be put in place to further protect public health.