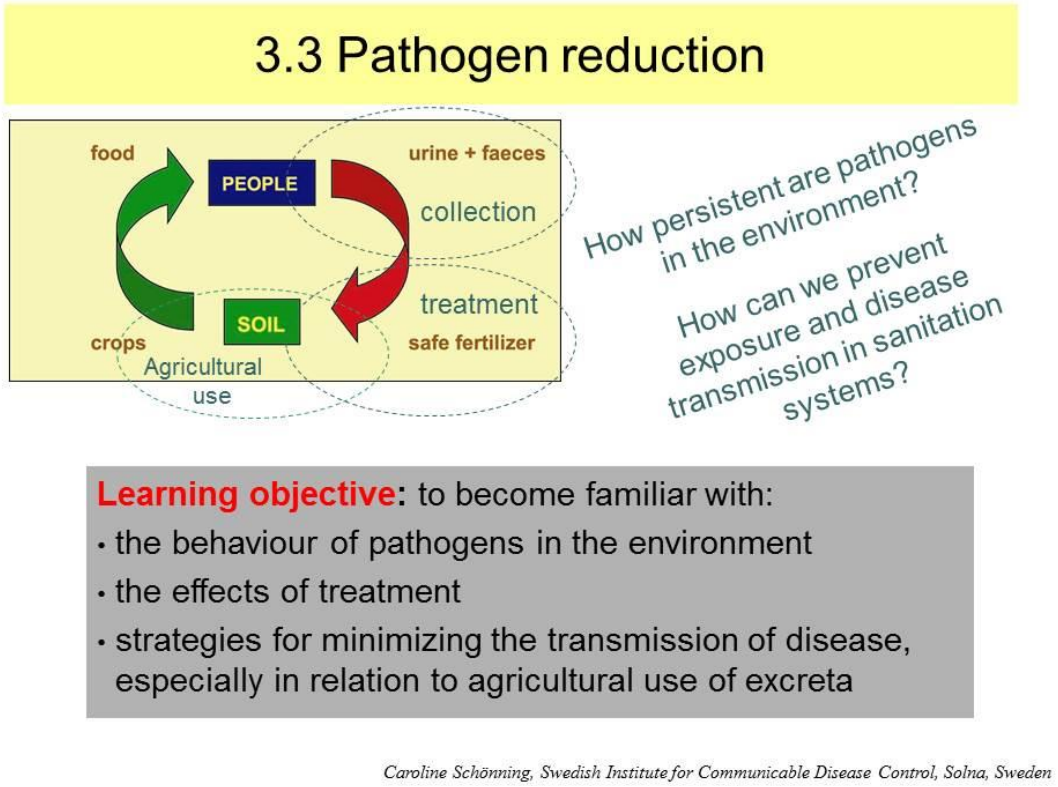

Pathogens are present in all flows in sanitation systems (Module 3.2). Collection and treatment of the various waste streams like greywater, urine and faeces is necessary in order to protect water sources and our immediate environment. When waste fractions are recycled – or "reused" – as a resource in agriculture, new transmission routes for pathogens may be introduced. The management of the new system must minimize the risk of disease transmission through treatments and other barriers that prevent humans and animals from being exposed to pathogens.

This module examines conditions under which pathogens will survive or perish in systems and in the environment. It discusses the types of barriers that can be used to reduce pathogens and decrease health risks in sanitation systems where the waste fractions are intended for agricultural use. The module builds on recent research with the purpose to provide an understanding of the possibilities to employ various barriers to reduce health risks.

The Module has a focus on excreta. By closing the so called nutrient loop, that is ensuring the return of nutrients in urine and faeces to agriculture, we can further improve health by increasing food production. When people´s nutritional status is improved it makes them less susceptible to infectious diseases. However, this recycling of nutrients needs to be done in a safe way and this involves the safe collection of the excreta, safe treatment (before use), and the safe use of the products.

In Modules 3.4 and 3.5 there are further descriptions of how barriers are used in a systematic way and guidelines are developed for safe reuse of excreta. More practical information on how to treat excreta is included in Chapter 4.

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Transmission of infectious disease during reuse

3.3–2

- Mexico, untreated wastewater: 33% higher risk of diarrhoeal diseases (Cifuentes et al. 1998)
- Israel (kibbutz), partially treated stabilization pond effluent: two-fold excess risk of enteric disease in 0-4 year-old age group (Fattal et al. 1986)
- No recorded incidents associated with ”appropriately treated” wastewater (Cooper & Olivieri 1998)
- National Research Council (NRC, USA, 2000) evaluated 23 studies: no proof for either risk or non-risk for reuse of sewage sludge
- Risk assessment a valuable tool

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Excreta and other waste products always contain pathogens. The cited studies above prove that there are potential increased health risks when using treated excreta or other waste products in agriculture. These risks can be managed by limiting the exposure to pathogens and to reduce the numbers of pathogens by introducing barriers such as treatment of waste. The relationship between the use of waste products and possible enteric disease is difficult to establish by epidemiological methods, but some studies have been carried out. The examples listed here lead to the following conclusions:

In Mexico, children from households that irrigated gardens with untreated wastewater had a higher prevalence of diarrhoeal disease compared to children living in areas where untreated wastewater was not utilised (“rainfall villages”). The risk for diarrhoeal disease was 33% higher.

According to a 1986 study the use of partially treated wastewater in Israel resulted in a doubling of the rate of enteric disease among children. However, a summary of research involving more advanced wastewater treatments found no evidence of increased enteric disease. Regarding the use of sewage sludge, the National Research Council (NRC) in the USA evaluated a number of studies where individuals were exposed to sludge and concluded that there was no proof that the health risk increased or decreased. The NRC further stated the risks need to be further evaluated.

Epidemiological studies are expensive and often complemented with the valuable cost-effective tool of risk assessment. Risk assessments are discussed further in Modules 3.4 and 3.5. An aligned issue touched upon is how risks are perceived in varies regions of the world and between individuals. This module focuses on survival and inactivation of pathogens.

Estimated survival times for microorganisms in faeces, sludge, soil and on crop

3.3–3

Times given in days if not otherwise stated

Microorganism	Faeces and sludge[a] 20-30°C	Soil[a] 20-30°C	Soil[b] absolute max[c]/ normal max	Crop[a] 20-30°C	Crop[b] absolute max[c]/ normal max
Bacteria			1 year/ 2 months		6 months /1 month
Faecal coliforms	<90 normally <50	<70 normally <20		<30 normally <15	
Salmonella	<60 normally <30	<70 normally <20		<30 normally <15	
Virus	<100 normally <20	<100 normally <20	1 year/3 months	<60 normally <15	2 months /1 month
Protozoa[d] (Amoeba)	<30 normally <15	<20 normally <10	10/2	<10 normally <2	5/2
Helminths (egg)	several months	several months	7 year/2 year	<60 normally <30	5 months /1 month

[c] Absolute maximum times for survival are possible during unusual conditions, such as at constant low temperature or at extermely protected conditions.

[d] Data is missing for Giardia and Cryptosporidium. Their cysts and oocysts, respectively, probably survive longer than the times stated here for protozoa.

(*Faechem[a] 1983 and Kowan[b] 1985, in EPA 1999*)

Microorganisms cannot live forever, but perish for various ‘natural’ reasons – just like human beings. Earlier, the literature often defined survival times of indicator bacteria and pathogens as the time it takes for “total inactivation”. However, a total inactivation cannot be achieved in practice, only in theory. Only sterilization can kill all microorganisms, but this is only economically possible to achieve in a laboratory. Therefore, a zero risk cannot be the aim for any sanitary system which converts organic waste to fertilizers.

The above table summarizes some commonly used references and illustrates the variations in survival between different groups of organisms. The general impression is that bacteria, viruses and protozoa have strikingly similar survival times in faeces, soil and on crops in the temperature range of 20-30^{o}C. Helminths, on the other hand, often survive for longer periods than other microorganisms. Yet, some studies have found bacteria like Salmonella alive in the soil after a number of years, despite a stated survival time of just days!

It should be noted that in commonly used laboratory procedures for detecting microorganisms, it is not possible to determine whether inactivation is total. For each type of organism there is a minimum concentration below which it is not possible to specify the number present. That is, results will not state “there are no organisms” but rather, that there are less than 1 or 10 per ml or per gram (numbers are given here as examples). Thus, ‘total inactivation’ is too crude a concept and therefore complemented with the time it takes for a, say, 90% reduction, called T_{90}.

Keeping these circumstances in mind, the table on survival time still gives guiding information that is helpful in practice. For instance, if faecal matter or sludge is stored for more than a year, most pathogens are expected to have died off. Even if a 100% inactivation is not expected or necessary, treatment methods can be introduced to manipulate or speed up the inactivation of pathogens.

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3.3–4

Inactivation of microorganisms in faeces

Organism to be modelled	4°C/low temp range	20°C/high temp range
E.coli*	T_{90} = 70-100 days	T_{90} = 15-35 days
Enterococci*	T_{90} = 100-200 days	Same as 4°C
Bacteriophages	T_{90} = 20-200 days	T_{90} = 10-100 days
Salmonella*	T_{90} = 10-50 days	
EHEC*	T_{90} = 10-30 days	Same as 4°C
Rotavirus	conservative model – no reduction T_{90} = 100-300 days	T_{90} = 20-100 days
Giardia	T_{90} = 15-100 days	T_{90} = 5-50 days
Cryptosporidium	T_{90} = 30-200 days	T_{90} = 20-120 days
Ascaris	T_{90} = 100-400 days	T_{90} = 50-200 days

*Possible growth not taken into consideration *(Arnbjerg-Nielsen et al., 2005)*

The ‘natural’ die-off times for specific microorganisms in faecal matter is given in the table for two temperature ranges.

Since “full inactivation” of pathogens cannot be attained for a long time (years) in soil, sludge or faeces, instead so-called T_{90}-values are often used. The T_{90}-value is the time required to inactivate 90% (or 1 log_{10}) of the microorganisms. The survival times given in this table are based on a literature survey of survival experiments performed using faeces and other similar material such as manure and sludge. Studies of inactivation in faeces are few and other studies had to be considered in order to estimate the T_{90}-values. These figures are later used in a risk assessment – see Module 3.5.

As can be seen, the results for different organisms vary considerably both between species and between temperature ranges. However, two observations on slide 3.3-3 seems to hold; for the higher temperature range the variation between species is rather small, and the survival time in a colder environment is substantially longer than in warmer environment.

The WHO guideline (2006) to store faecal matter for more than a year seems to be reasonably safe at the T_{90} inactivation level. More recent results from inactivation studies are presented in Chapter 4 to give practical advice and rules of thumb about how to treat excreta. In this chapter you can also find explanations of how inactivation can be calculated and expressed, especially in relation to temperature.

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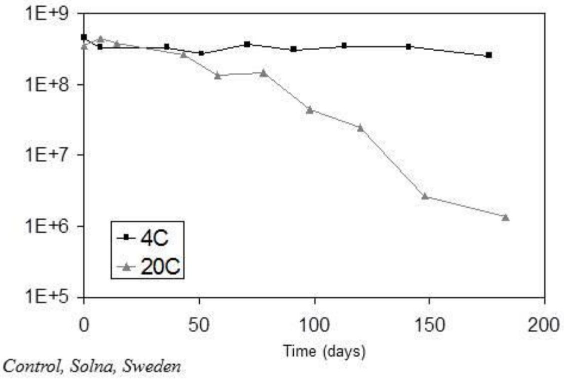
3.3–5

Survival of microorganisms in human urine

Organism group (ex.)		**Survival time**
Bacteria (*Salmonella*, *E. coli*)	-	**Short** (T_{90} = days)
Protozoa (*Cryptosporidium*)	-	**Average** (T_{90} = ~1 month)
Virus (rotavirus, bacteriophage)	-	**Long** (no reduction at 4°C, T_{90} = ~ 1-2 months at 20°C)

Factors that speed up die-off

- elevated **pH** (7 → 9, urea → ammonia)
- higher **temperature**
- lower **dilution**



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Urine is largely sterile in the body (see 3.2-17). Sill, urine in a urine-diverting toilet may be mixed with faecal matter through cross-contamination. What happens if enteric pathogens end up in the urine? Research on the survival of pathogens in urine during storage provides the following answers (http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-3090):

Bacteria are inactivated within days. Protozoa, represented by *Cryptosporidium* had a T_{90} of one month, whereas viruses were the most persistent organisms with no reduction at 4°C, and a T_{90} of 1–2 months at 20°C (see graph above).

The temperatures investigated here correspond to minimum and maximum temperatures in a Northern European climate. Since a higher temperature generally results in a faster inactivation it is likely that T_{90}-values will be lower in tropical climate, which is to say that a shorter time is needed for the same level of treatment.

There are other factors that promote inactivation (next slide). For instance, pH in urine increases from 7 to around 9 even after a short transport through a pipe. The reason is that urea is transformed to ammonia. This gas can kill pathogens.

Parameters affecting microbial survival in the environment

3.3–6

Temperature	Low temperature prolongs survival. Inactivation if >40°C, treatment processes 55-65°C.
pH	Neutral pH (7) beneficial for survival. Inactivation – if highly acidic or alkaline conditions.
Moisture	Moisture (e.g. in soil) favours the survival. Inactivation – if drying condition.
Solar radiation/ UV-light	Inactivation – by natural solar radiation or UV-lamps.
Other microorganisms	Longer survival in sterile material. Inactivation – competition and predation.
Ammonia	Often affects microorganisms negatively. Inactivation – by ammonia produced at high pH.
Nutrients	Needed for growth of bacteria. Inactivation – if lack of nutrients.
Other factors	Oxygen availability, chemical compounds.

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Understanding why pathogens survive and perish in the environment is crucial for developing measures to reduce pathogens. The above table lists important parameters for the survival and inactivation of microorganisms.

Temperature – even if human pathogens are adapted to the body temperature of 37°C, they may favour other temperatures in the environment. A lower temperature (but above 0°C) generally prolongs survival. The higher the temperature is, the quicker the inactivation. For effective treatment in compost heaps, temperatures above 55°C are preferable, and sometimes required in legislation. Temperatures of at least 120°C are needed to kill bacterial spores.

pH – most pathogenic microorganisms are adapted to a neutral pH (7) and can potentially be killed by a (significantly) higher (alkaline) or lower (acidic) pH-level.

Moisture – living organisms require moisture for their survival so drying material (like soil or faeces) has a negative effect on pathogens. However, some life stages of parasitic protozoa and helminths can be quite resistant to drying, e.g. Ascaris requires <5% humidity.

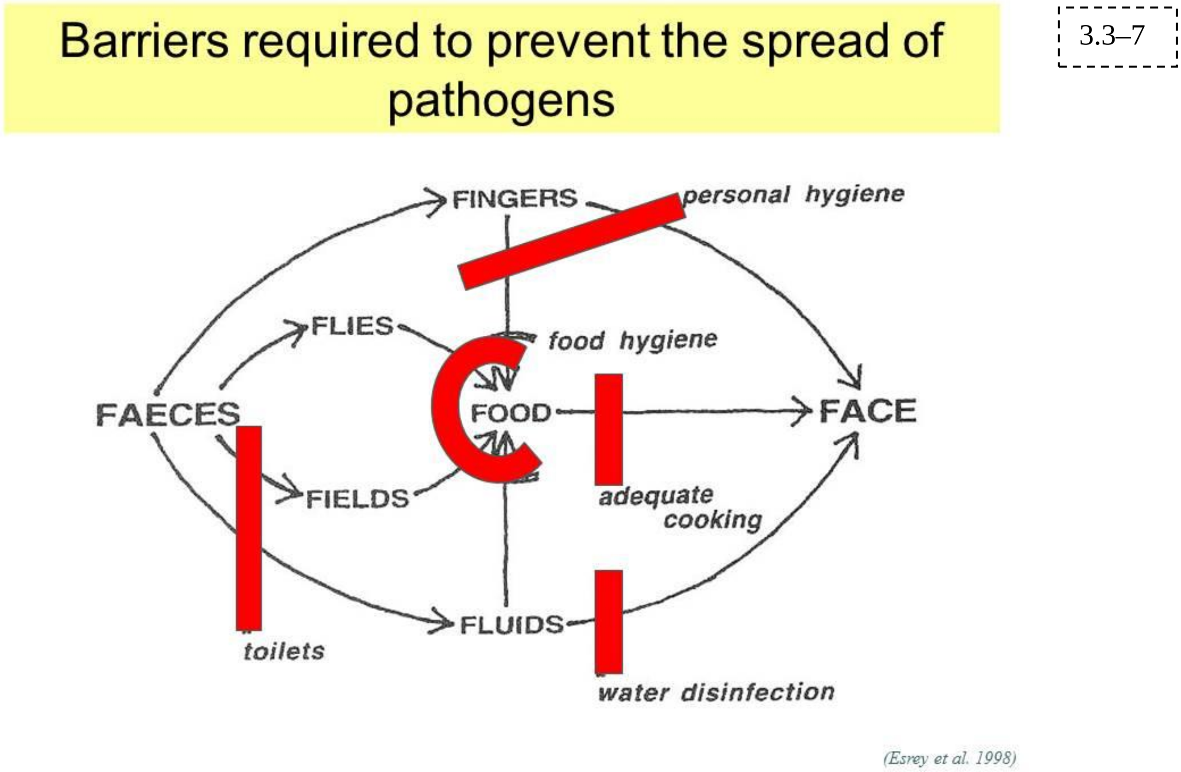
Solar radiation and UV-light - is a natural factor that can kill pathogens. It is therefore used in water treatment systems to reduce the number of pathogens.

Microorganisms will affect each other by predation and competition, and pathogens survive longer in sterile water than in water in which there are other organisms.

Ammonia is a compound that plays an important role in treating waste such as sewage sludge and faeces. Ammonia kills pathogens and can be generated at high pH-level by treatment with lime or urea (see Chapter 4).

Nutrients – presence of nutrients can affect the survival of bacteria, since they can both grow and multiply in such environment. Bacteria can also starve and die or become inactive for lack of nutrients.

Other factors such as oxygen or some chemical compounds can affect pathogens negatively.



Barriers refer to measures to limit people's exposure to pathogens either by an actual reduction of pathogens in the material (human waste, organic fertilizer or crop) or by actually preventing people (and animals) from coming into contact with the material. Returning to the F-diagram presented in Module 3.2, barriers to prevent the spread of pathogens from faeces include the following:

Toilets – the use of **toilets** to collect **faeces** reduces exposure compared to the practice of open defecation. Defecation in **fields** where **food** is produced, introduce pathogens on crops and runoff may contaminate the water in nearby streams (**fluids**).

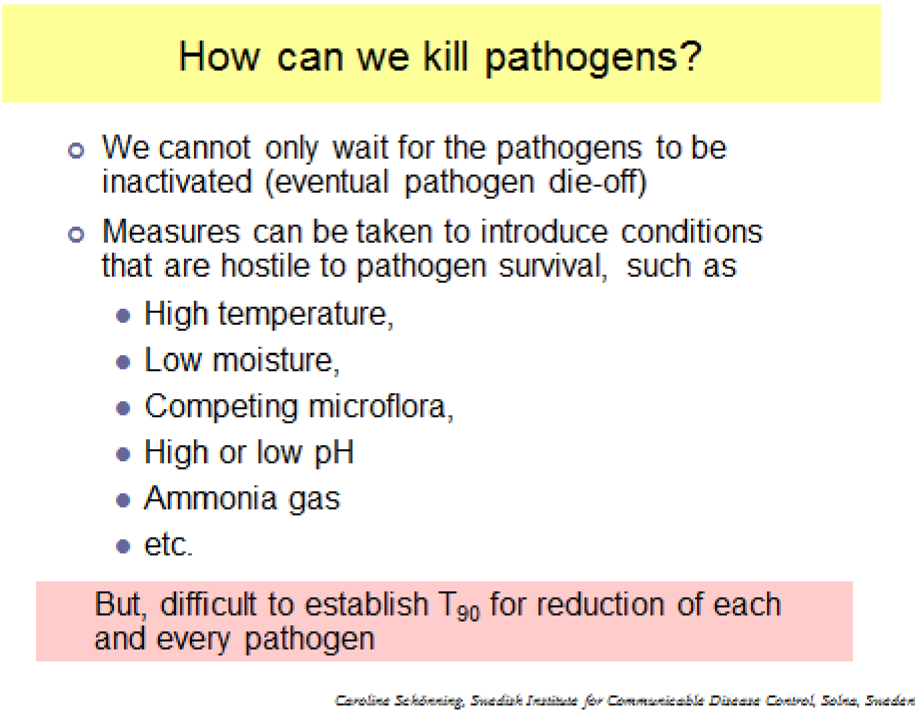
Water disinfection – is practised on all large-scale water production facilities, but can also be applied on a small scale. However, it is not easy to find a chemical or a filter that removes all pathogens. To boil unclean water, before drinking it, is therefore a common practice. It is important that water is stored in a safe way so that further contamination is avoided.

Personal hygiene – to wash hands is a simple measure to improve the health situation if water is available. It prevents the transfer of pathogens from **faeces** or the environment to the **food** or directly to your **face** (mouth, nose, and eyes). Some pathogens are sensitive to alcohol gel whereas others are not and general hand washing, preferably with soap, is more effective.

Adequate cooking – microorganisms thrive on stored food but by heating food it is possible to kill the pathogens. If a toxin has been produced by bacteria, it is however not possible to remove it by heating the food. Diseases caused either by infection or toxic reactions are generally referred to as food poisoning. Cooking also has little or no impact on the concentrations of toxic chemicals that might be present.

In practice, some communities rely on a barrier late in the food chain. For example, the old Chinese tradition to use faecal material in crop production is accompanied by household practice to heat all vegetables i.e. they are not consumed raw as in many other countries. Nevertheless, there is/has been a high prevalence of helminth infections in parts of the population. The ideal situation is to apply a set of barriers, since no single barrier is completely effective on its own, and relying on more than one barrier will increase safety (see also Module 3.4).

3.3–8



It is now known what species of pathogens are present and to have a fair idea of how many there are (Module 3.2). In this module, information is given about how long they survive in various environments, and the rate at which they are inactivated. We also know some simple measures as to how humans avoid exposure to pathogens (slide 3.3-7). The next issue is to see how pathogens can be manipulated or killed in order to reduce health risks.

Inactivation depends on the microorganism´s sensitivity to environmental factors such as temperature and moisture (see previous slide). It is possible to alter these conditions to increase the inactivation rate, but it is difficult to state the approximate time it will take to achieve a “total” inactivation in a specific environment. Inactivation is crucial in managing the treatment of excreta and other organic wastes. Bacteria can multiply under favourable conditions, but that is not the case for the other groups of microorganisms e.g. viruses.

We utilise the information on positive influences on survival and try to introduce the opposite conditions. For instance, to raise pH or temperature, or to reduce oxygen levels. The next set of barriers relates to treatment of wastewater, sludge, faecal material, and urine.

3.3–9

Expected removal (log_{10}) of micro-organisms by wastewater treatment barrier

Process	Bacteria	Helminths	Viruses	Cysts
Primary sedimentation				
Plain	0-1	0-2	0-1	0-1
Chemically assisted	1-2	1-3	0-1	0-1
Activated sludge	0-2	0-2	0-1	0-1
Bio filtration	0-2	0-2	0-1	0-1
Aerated lagoon	1-2	1-3	1-2	0-1
Oxidation ditch	1-2	0-2	1-2	0-1
Disinfection	2-6	0-1	0-4	0-3
Waste stabilization ponds	1-6	1-3	1-4	1-4
Effluent storage reservoirs	1-6	1-3	1-4	1-4

Large variations depend on organism and difficult to predict

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We start with wastewater and sludge treatment (see also Module 4.6) before expanding on treatment of faeces and urine.

A wastewater treatment plant is not optimized for pathogen inactivation/removal but has other primary functions, mainly reducing nutrients and solids. Each step in a treatment plant constitutes a barrier to transmission of disease. However, new routes are established via air, seepage and sludge, and have to be kept under control. The table above shows approximate log_{10} removal rates of various types of microorganisms in the effluent by different wastewater treatment steps. Such removal is due to both die-off and actual removal, for example by sedimentation processes or adhesion to particles.

As can be seen in the table, low-tech systems such as waste stabilization ponds can result in high rates of removal of pathogens. Treatment systems like this are further described in Module 4.6. Even disinfection by chlorination fails to reduce cysts (or oocysts) like Cryptosporidium which is very resistant to chlorine. Therefore, it remains important to include barriers preventing people and animals from coming in contact with the outgoing wastewater.

The greywater contains much fewer pathogens than household wastewater (see 3.2-18/19), but even treated greywater contains a range of contaminants, among them pathogens. Treatment is required, but what kind of treatment is appropriate depends on the constitution of the greywater and its subsequent use. For instance, specific risks are related to irrigation such as aerosol and cultivation. Irrigation methods can themselves be important barriers e.g. sub-surface irrigation. Ponds represent a case where the treatment facility itself constitutes a risk both from a hygienic perspective and due to accidents e.g. falling into the pond. If the treated greywater is used for groundwater recharge and subsequent drinking water production, the infiltration process needs to reduce the pathogen population sufficiently. Greywater systems and treatment are elaborate on in Chapter 4.

Greywater treatment

3.3–10

- Treatment to remove grease, N, P, chemicals….and pathogens (see chapter 4)
- Choice of treatment method dependent on the intended use
- Specific risks of use:
  - Irrigation, subsurface
  - Treatment in ponds – limit exposure
  - Infiltration, drinking water
- Handling to avoid smell

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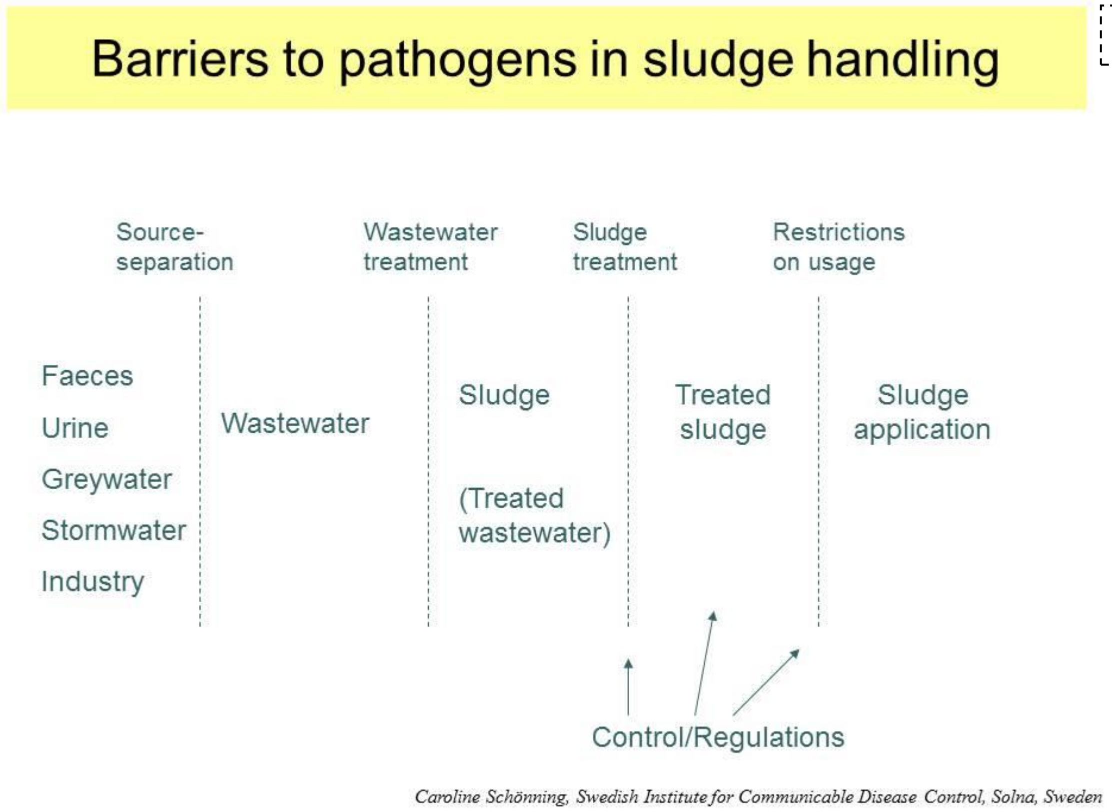
The greywater flow contains much fewer pathogens than household wastewater (see 3.2-18/19), but even treated greywater contains a range of contaminants, among them pathogens. Treatment is required, but what kind of treatment is appropriate depends on the constitution of the greywater and its subsequent use.

Initially, greywater must be treated in order to avoid smell, which is likely to be caused by anaerobic conditions. Studies of greywater treatment show large variations in the effectiveness and efficiency (see Module 4.7). Additional barriers may be needed to prevent exposure.

3.3–11



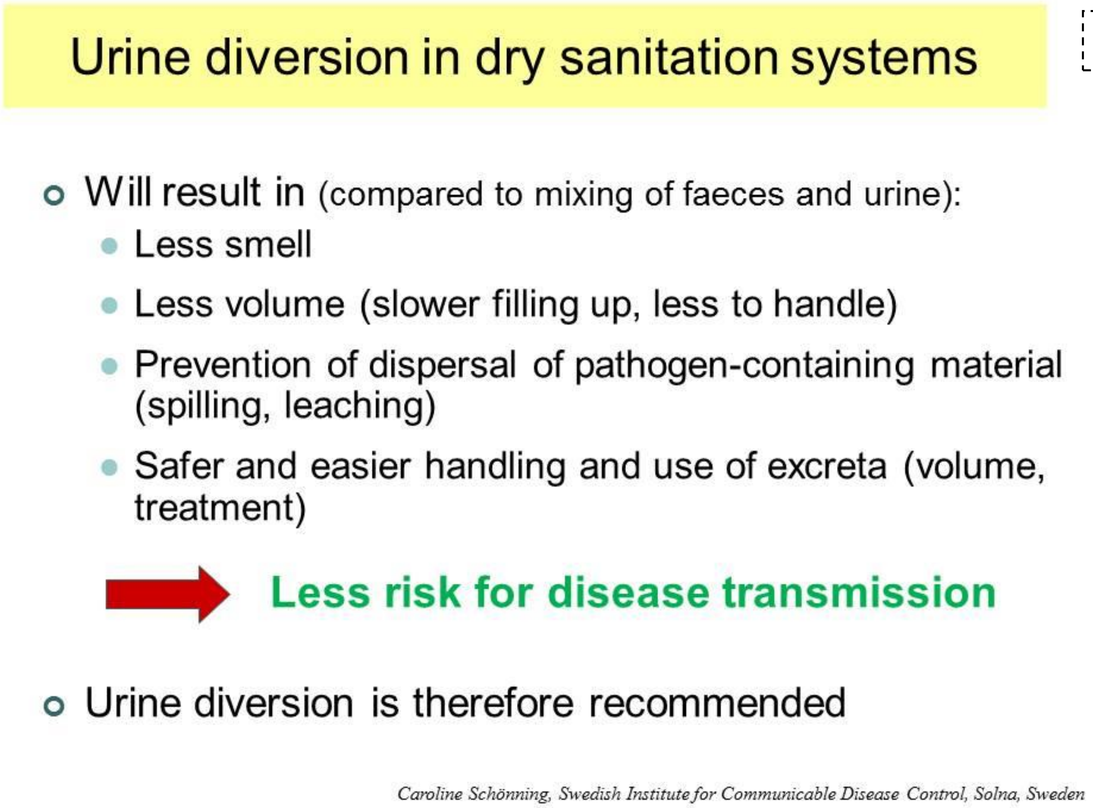
Another example of barriers is in relation to managing sludge, where sewage sludge can be compared to other types of organic wastes. A kind of '*liquid waste hierarchy*' can be applied, starting from reducing the volume and hazardous content of the sludge (see 1.3-8). Keeping waste flows separate, makes it is easier to treat each flow separately e.g. greywater with or little pathogen load. Also, each flow has less varied composition and some streams have few hazardous compounds.

After treatment the bulk of pathogens are found in the sludge (see 3.4-6), while some remain in the treated effluent and some are found in sediments in the treatment plant. Sludge can be treated further (see 4.7-28) by drying or storage, while incineration should be avoided since this process makes plant nutrients inaccessible in the ashes.

Restricting the use in agriculture constitutes a major barrier and limits exposure of humans and animals to pathogens. The European Union has issued detailed quality requirements for substances in sludge and allowed application rates on different soils (http://ec.eurpoa.eu/environment/waste/sludge/).

In addition to content of the sludge, behavioural restrictions make up important barriers for transmission of pathogens and disease (further discussed in Module 3.4).

3.3–12



By separating urine from faeces in dry toilets several benefits can be obtained. There will generally be less smell, there will be smaller volumes to handle and the collection chamber will not fill up as quickly. Since the remaining material will be drier there will be less risk of spilling and leaching to groundwater and this can facilitate further treatment. All these factors can contribute to a reduction of the risk of disease transmission. It is therefore possible to advocate the implementation of urine diversion, and that is even if the urine is not reused.

Diversion of urine can also have large benefits in pipe-bound and water-flush systems.

Treatment of faeces as barrier

3.3–13

- **Primary treatment in dry toilet**
  - Adding drying material reduces pathogen load
- **Storage**
  - Ambient conditions
- **Biological methods**
  - Composting (heat, microbial competition, pH-changes)
  - Anaerobic digestion (competition, pH-changes)
- **Chemical treatment**
  - Alkaline treatment
    - Ash, lime (pH-elevation and desiccation)
    - Urea (ammonia)
- **Incineration**

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Excreta may be flushed with water and often together with toilet paper. This so called black water is commonly mixed with greywater in a sewer. In this Module, however, exposure is related to the singular flow of faecal matter.

A **primary treatment** occurs in dry toilet collection vaults and is influenced by the toilet construction and the habits of the users. For instance, if users add some material (lime, ash, sand, dried compost matter, etc.) to cover the faeces biological and chemical processes are initiated. If desiccation or a pH-increase occurs, this “treatment” can reduce bad odour as well as lower the health risks involved in subsequent handling of the faecal material.

Storage is a simple and effective treatment method both on-site and off-site. The storage place should be odour-free and faeces should be covered and seepage should be controlled. Since storage is done at ambient conditions, the reduction of pathogens will vary tremendously. However, further measures can be taken to improve the reduction while storing faecal matter.

Biological treatment is composting with organic matter in high temperature or anaerobic digestion producing biogas at ambient temperature (see Module 4.4 and 4.6).

Chemical treatment involves the addition of a chemical, either from a “natural” source such as wood ash or pure urea. The increase in pH and the production of ammonia that occurs in the controlled type of urea treatment (ammonia treatment) is effective in reducing pathogens. pH can be raised up to 12 by adding lime and effectively kill micro-organisms. Adding ash also raises pH level and desiccates the faeces, both of which inactivate pathogens. The latter is often used in small–scale treatment. Thorough mixing of chemicals with the faecal material is a crucial point.

Incineration of faeces is not advisable since the material is too moist and requires energy. Also, incineration tends to make N to disappear and P and K non-available to plants (see 1.3-8).

Storage of urine as a barrier

3.3–14

- The most appropriate treatment method
- Other methods tried out in order to reduce the volume
  - Easier handling for agricultural use
- Storage with low air exchange (tight containers) best method to keep the nutrients in urine
- Only necessary in large-scale systems
- Existing guidelines in module 3.4

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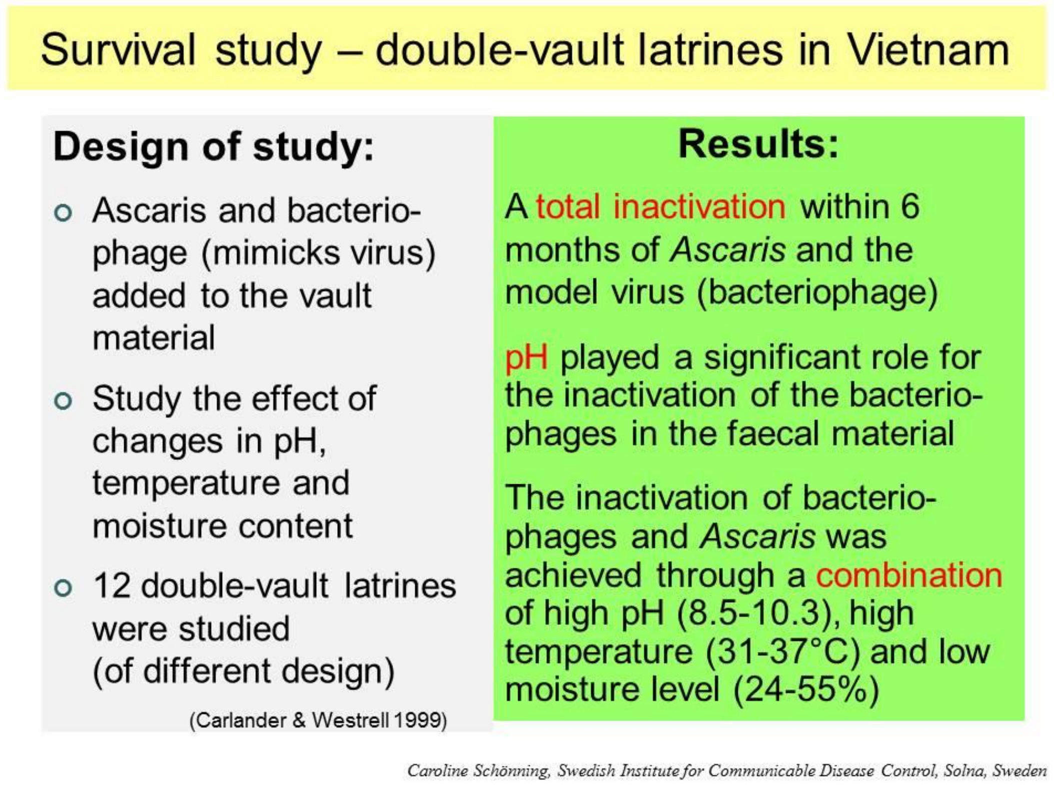
Storage is at present seen as the most viable method for the treatment of urine. Other methods have been tried, but more for the purpose of producing a fertilizer product that is easier to handle. However, a lot of energy is required to dry urine and most of the nitrogen is lost in the process. Urine is a well balanced fertilizer and it is considered most resource efficient to keep the urine as it is. Still, storage has to be in airtight containers to minimize nitrogen losses (about 1% lost instead of more than half in aerated storage). Storage for hygienic reasons is only considered necessary in large-scale systems. At household level the urine may be used directly, since the risk for disease transmission is considered low (WHO, 2006). If and when the volume of urine could be reduced without losing its nutrient content, transport and storage costs will go down and make the product competitive with chemical fertilizers.

An example of a risk assessment for reusing urine and existing guidelines is presented in Module 3.4. The agricultural use of urine is discussed in Module 4.8.



3.3–15

A double-vault dry latrine placed above ground was developed in Vietnam in the 1950s. It is mainly being used in rural areas. The long use made it interesting to study its pathogen reduction capability. Ascaris eggs and Salmonella bacteriophages (viruses that infect bacteria, in this case the Salmonella strain *salmonella typhimurium* 28B) was added to the faeces in twelve vaults and studied over a period of six months. Three environmental parameters were measured – pH, temperature and moisture.

By statistical analysis it could be concluded that:

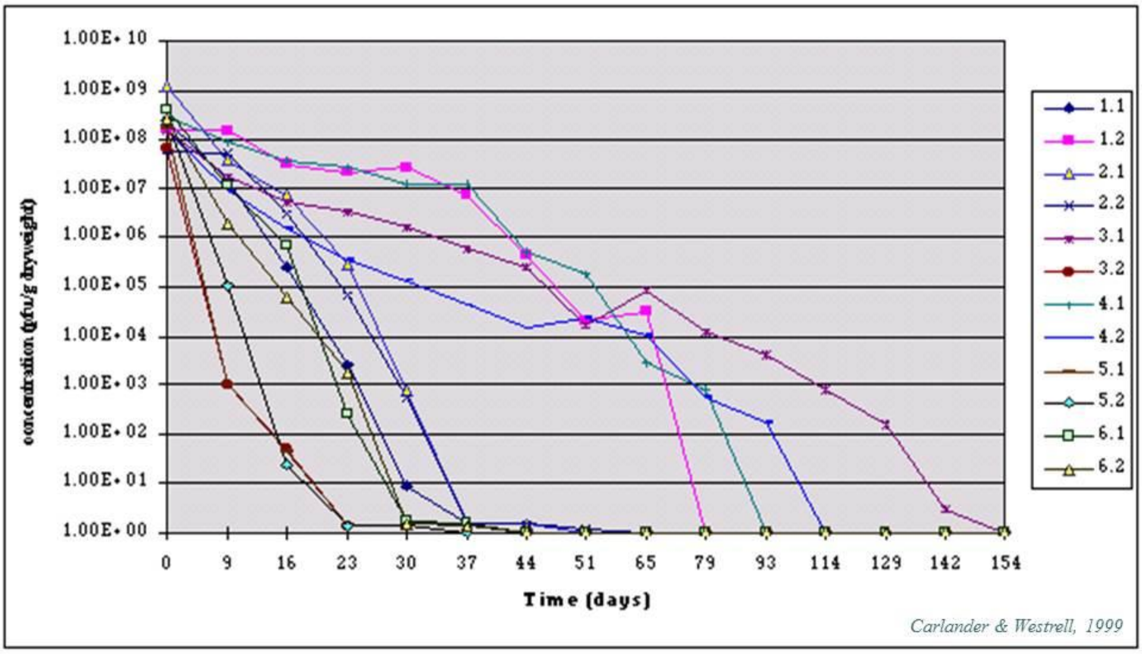
- A total inactivation of the sturdy *Ascaris* ova (possible to count due to their big size) and the model virus (bacteriophage) was achieved within 6 months.
- pH played a significant role in the inactivation of the bacteriophage in the faecal material
- The inactivation of the bacteriophage and *Ascaris* was achieved through a combination of high pH (8.5–10.3), high temperature (31–37°C) and low moisture content (24–55%).

It was not possible to determine the relative importance of the different factors on pathogen inactivation.

The detailed measurements are given in the following two slides.

3.3–16

Reduction of *Salmonella typhimurium* phage 28B in latrines over time for different measures



As can be seen, the phages were reduced to below the detection level in about 1–2 months in eight toilets, whereas they survived for up to 6 months in one.

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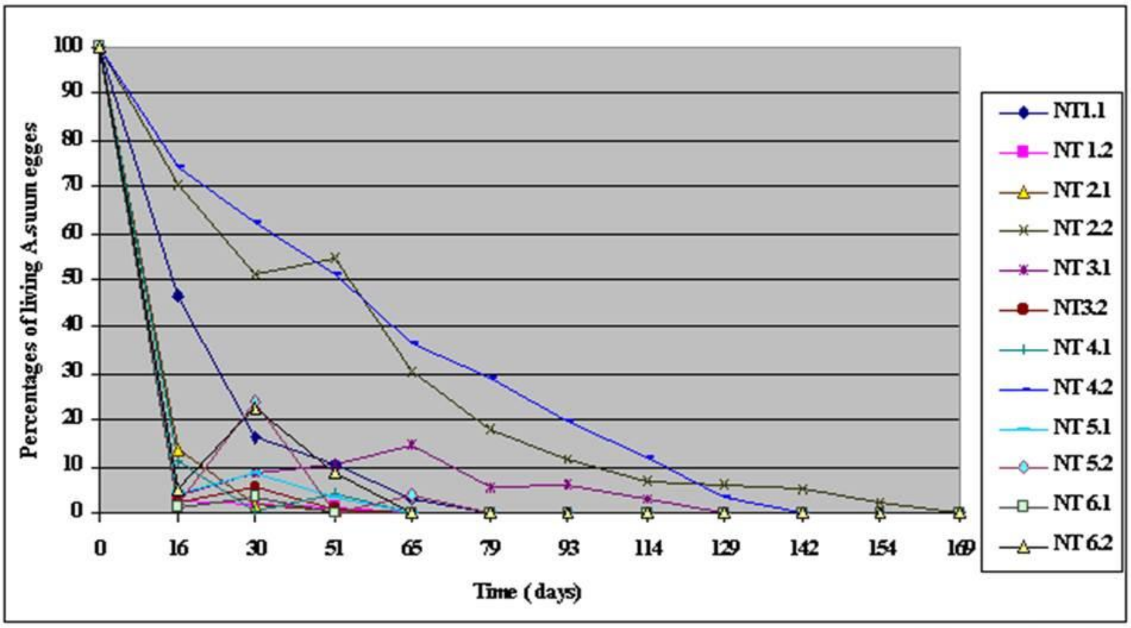
Reduction of *Ascaris suum* eggs

3.3–17



(Carlander & Westrell 1999)

Looking at Ascaris eggs in the same toilets, the situation was somewhat similar with more rapid inactivation in most of the toilet vaults, and prolonged survival in a few vaults.

Interestingly, a comparison between Ascaris and Salmonella (previous graph) shows that the reduction in toilets NT 4.2, NT 3.1 and NT 2.2 is very slow for both, and one can only speculate about the reason for this.

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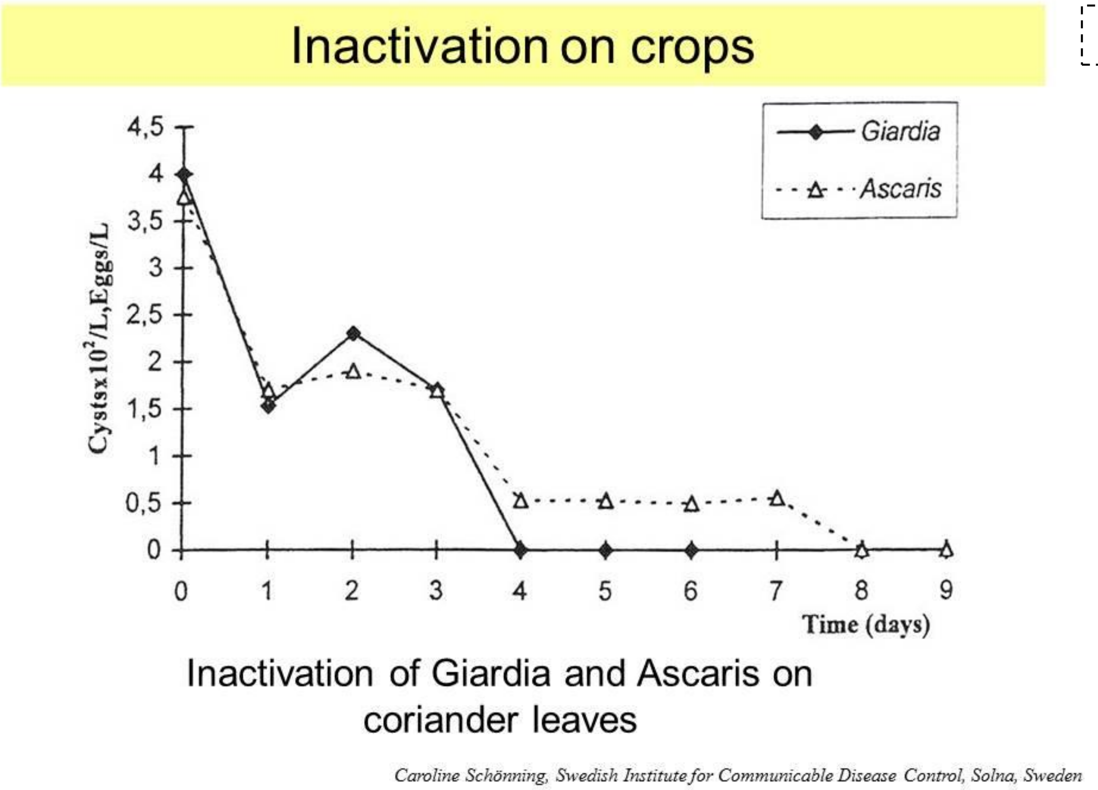
3.3–18



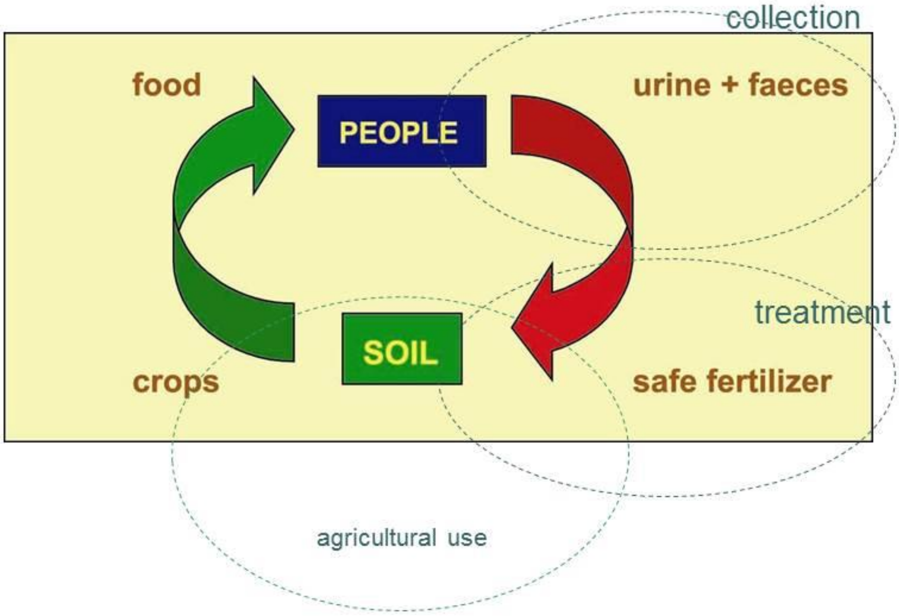
Pathogens can be transmitted via food (see 3.3-5) and they may originate from pathogens on crops. The spice coriander is made of grounded leaves and used as a condiment directly added to food. Therefore, pathogens have direct route from the crop to mouth. The graph displays a 'natural' reduction of Giardia and Ascaris on coriander leaves. This example shows a quite rapid inactivation of *Giardia* (4 log reduction in 4 days) and of Ascaris (4 log reduction in 8 days).

Inactivation of pathogens on crops is an important barrier for transmission of disease by food consumption. The above result supports the rule of thumb to do the last watering of leafy crops days before harvest.

Module 3.4 deals with risks of transmission in agriculture.

Closing the nutrient loop safely

3.3–19



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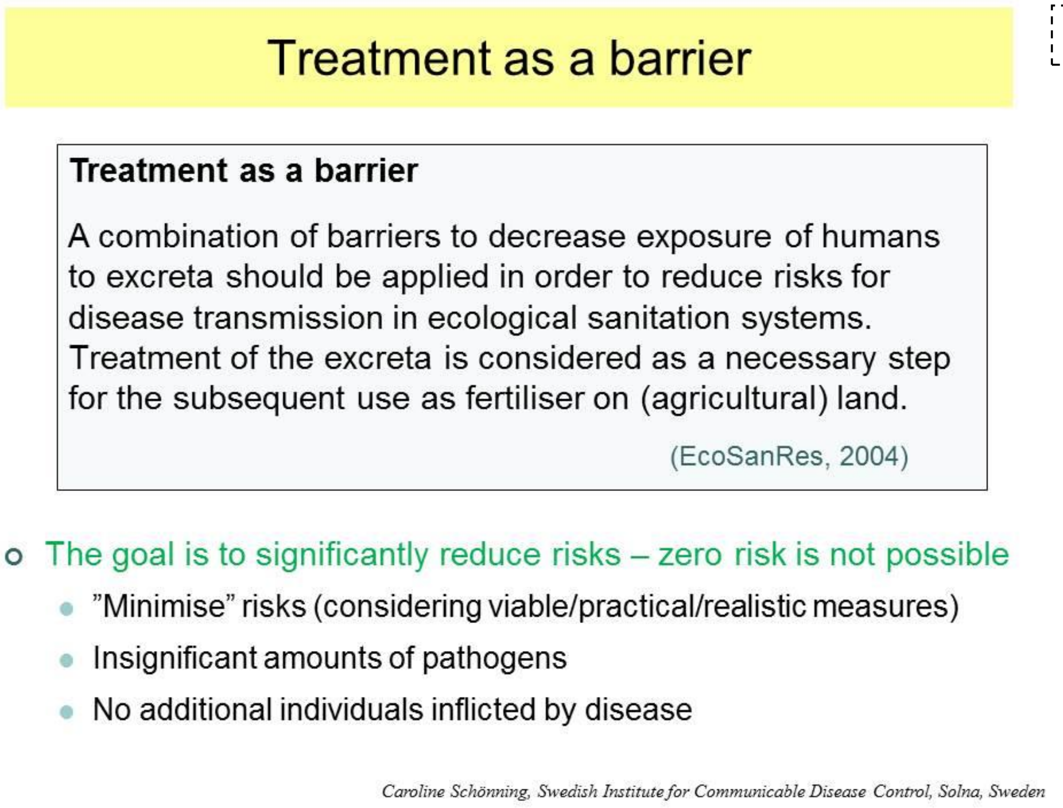
By closing the so called nutrient loop, that is ensuring the use of nutrients in urine and faeces in agriculture, we can further improve health by increasing food production. Thus, people´s nutritional status is improved which makes people less susceptible to infectious diseases. However, this recycling of nutrients needs to be done in a safe way and this involves the safe collection of the excreta, safe treatment (before use), and the safe use of the products. The purpose is to close the nutrient loop – but when it comes to pathogenic microorganisms the transmission routes need to be broken!

Other aspects of proper and optimal use of excreta and greywater, such as utilization of nutrients and choice of crops, are dealt with in Chapter 4.

3.3–20



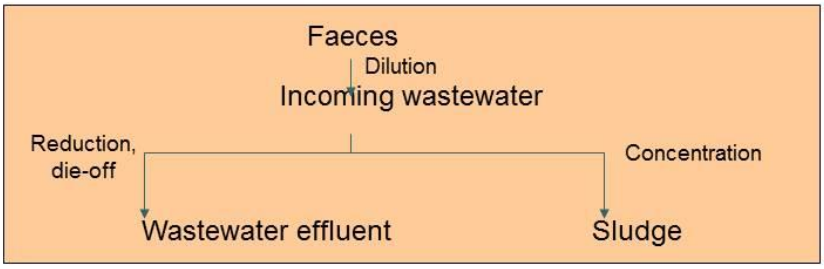
So, as stated: To reduce the risks from using excreta a combination of barriers is recommended. We see treatment as the main barrier in sustainable sanitation systems. The goal is to significantly reduce the overall risk, and it can also be viewed as minimizing risks or decreasing the number of pathogens to insignificant levels so that no additional cases of disease occur as a result of using excreta for fertiliser. As previously described, a total inactivation of pathogens is not achievable and it is not viable to aim at a zero risk for a sanitation system.

One example to prevent disease transmission is the various treatment steps for drinking water, e.g. filtration and disinfection. For waste products we can also talk about treatment as one barrier and other measures to limit people’s exposure to pathogens as other barriers. The exposure is decreased either by an actual reduction of pathogens in the material (that is, the human waste, the organic fertilizer or the crop) or by actually preventing people (and animals) from coming into contact with the material. A wider definition used by the WHO is that a barrier is any health protection measure. This definition includes measures such as chemotherapy and immunization, and health and hygiene promotion to decrease the risk of infection.

Wastewater treatment

3.3–21

- Treatment steps - barriers
- Microorganisms reduced by 70-99,99% in STP (Sweden)
- Treatment plants not optimised for pathogen removal
- Generally, no regulations on outgoing (treated) wastewater
- Disinfection is an efficient method, but causes other problems
- Sewage sludge has high concentration of pathogens



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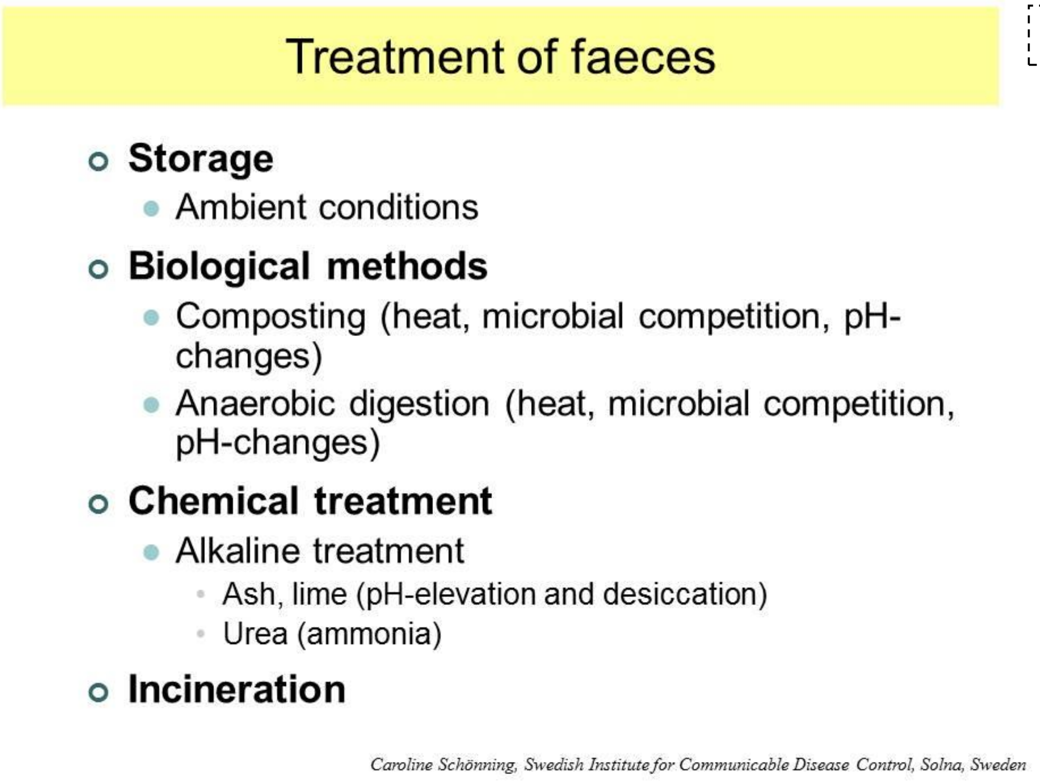
STP = Sewage Treatment Plant

Treatment of wastewater, sludge, faecal material, and urine is viewed as barriers. We start with wastewater and sludge treatment before expanding on treatment of faeces and urine.

Each step in the wastewater treatment plant constitutes a barrier to transmission of disease. However, wastewater treatment plants are not optimized for pathogen removal and have other primary functions such as reduction of solids and chemicals. It is only the final disinfection step that aims at pathogen reduction. In many countries disinfection is not included (if the wastewater is treated at all) and therefore it is important to include a barrier at the point of disposal – that is, there needs to be a barrier preventing people and animals from coming in contact with the outgoing wastewater. This can be done by choosing a suitable point of discharge. Under such circumstances part of the pollution problem may also be solved by dilution, for example by discharging effluent in the deep sea far from beaches or recreational areas.

3.3–22



To give an overview of possible methods for treating faeces the following categorization can be made**.** In Chapter 4, details and practical advice on how to perform treatments is given.

Storage can be considered the simplest method of treatment. The material is contained so that exposure and seepage are minimized and seepage. Exposure should also be minimized by choosing a proper place for the storage and the material should be covered. Since storage is done at ambient conditions the reduction of pathogens will vary tremendously, and storage requires proper containment.

Biological treatment means composting and anaerobic digestions, which both mainly rely on an increase in temperature to reduce pathogens as described in Chapter 4.

Chemical treatment involves the addition of a chemical, either from a "natural" source such as wood ash or pure urea. The increase in pH and the production of ammonia that occurs in the controlled type of urea treatment (ammonia treatment) is effective in reducing pathogens. On a large scale, lime treatment can be used, but is probably more common for sludge treatment, and results in a significantly elevated pH (pH 12). The addition of ash on the other hand is generally used in small–scale treatment, where some elevation in pH and desiccation result in pathogen inactivation. The chemicals need to be properly mixed with the faecal material to be effective.

Incineration of faeces is also possible but not commonly used since it requires lots of energy to burn such high-moisture material (see Chapter 4).

List of reference:

Höglund, C. (2001) "Evaluation of microbial health risks associated with the reuse of source-separated human urine" (http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-3090)