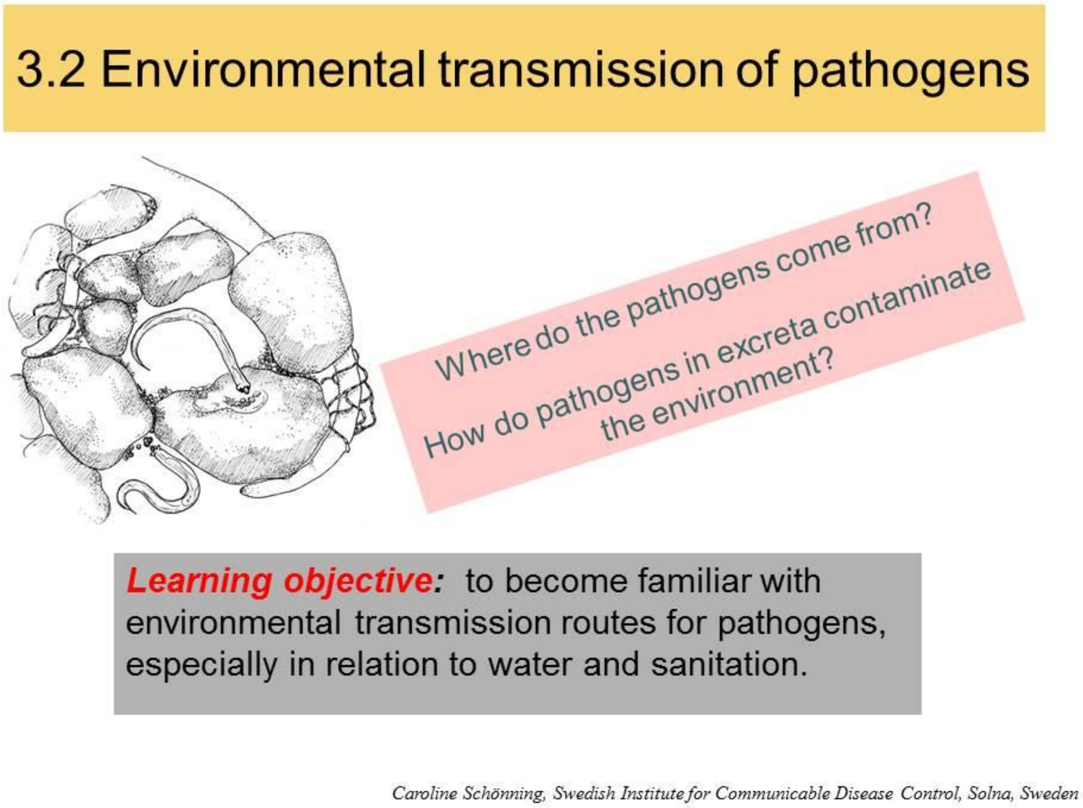


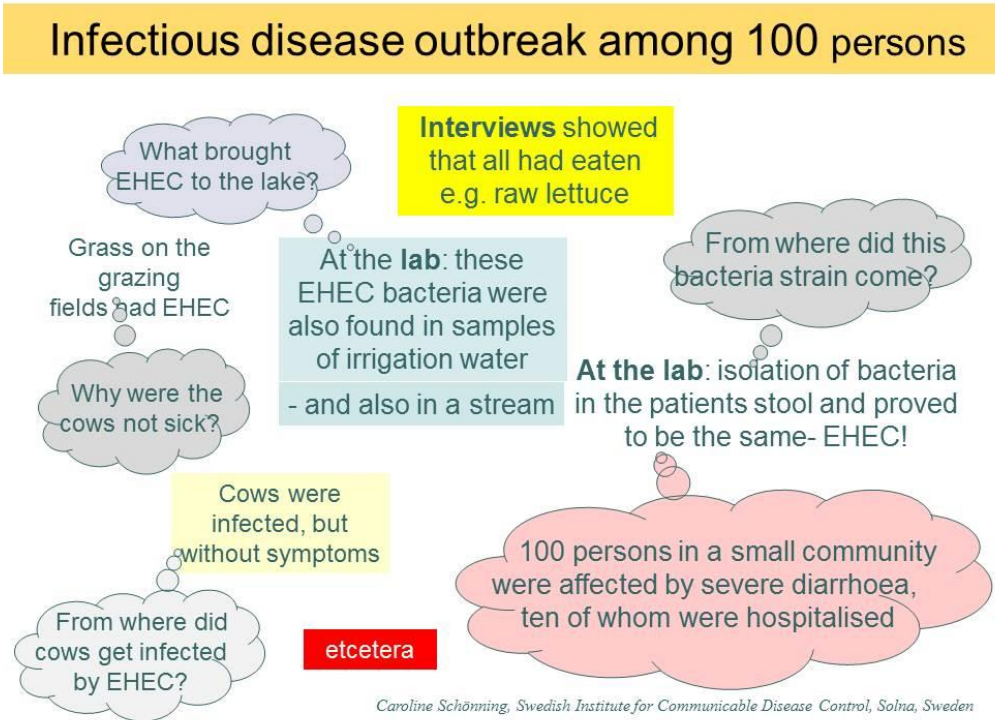
The environment around us is full of bacteria and other microorganisms. However, most of them are harmless to us. However, some cause disease – pathogens - and have to be kept under control. This is partly challenging partly easy. Societies have had hygienic rules for thousands of years, and some of these are encoded in religious scriptures.

In this module we deal with pathogens in different waste fractions and how they can be transmitted in the environment, resulting in potential exposure of humans and animals.

Chemicals in excreta and other waste fractions may also constitute a health problem, for example if they end up in our drinking water or on crops that we consume. This is mainly considered an issue for greywater in sanitation systems with diverted flows (see Chapter 4). Chemical aspects are partly covered in Module 4.8 (agricultural use). For wastewater, and especially for extracted sludge, there has been an intense debate regarding environmental pollution that is not within the scope of this module.

The module is essentially following the approach of (1) number of pathogens (2) exposure (3) diseases-response (4) vulnerability, and (5) barriers (see slide 4.5-7).

3.2–2



To trace disease-causing microorganisms is often like a detective narrative, and done by professional epidemiologists as well as individuals who wonder why they or others got ill. We use a real example of searching for a pathogen to highlight the main points when considering transmission of microorganisms in the environment.

An outbreak of severe diarrhoea occurred in a small community is Sweden. One hundred persons were affected and ten hospitalized. The national institute of infectious disease control was engaged to trace the cause and source of the outbreak. Lab tests of the sick persons found EHEC bacteria in their stool. This pathogen was the direct cause of the disease. But where did they come from? Interviews revealed that the sick persons all had eaten fresh lettuce, among a number of other food items. So, the team looked for EHEC bacteria in shops and food joints, and lab tests found the same strain of EHEC on lettuce leaves. A likely source of the disease was the water-washed lettuce. The water sources were tested, and the team found that a river carried the EHEC bacteria. Fine, but from where did the bacteria originate?

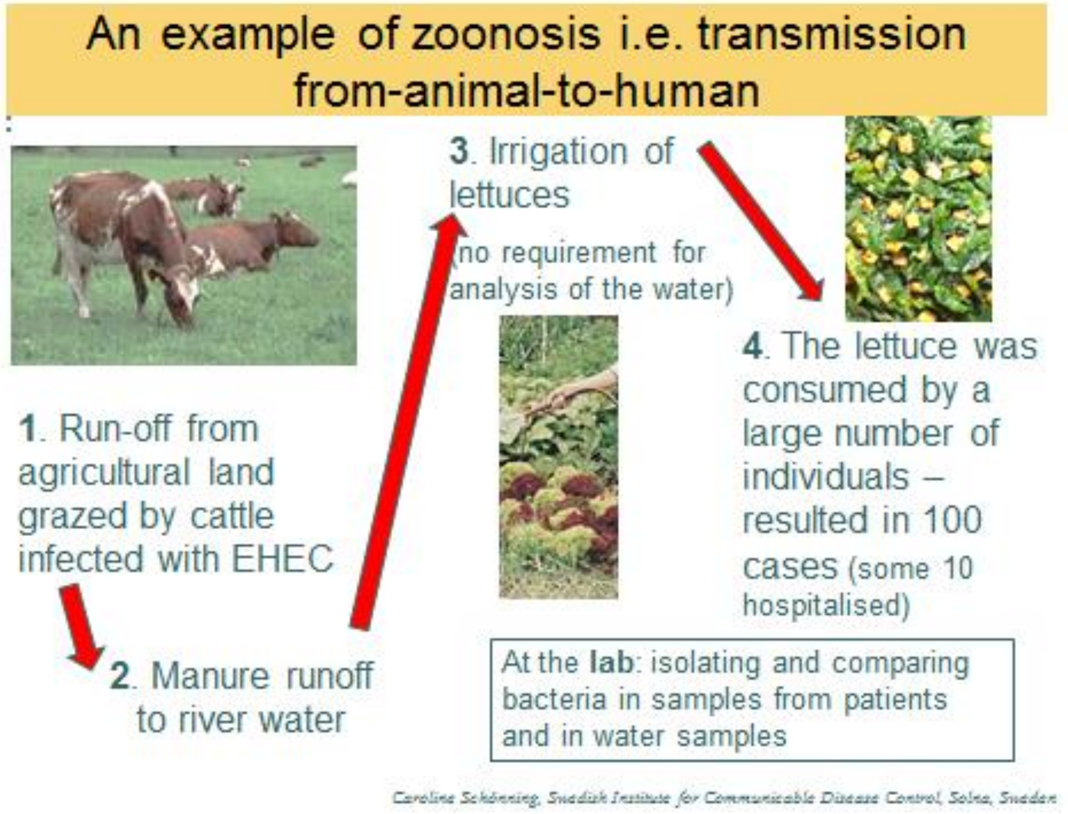
The team started to suspect a source in the environment. They checked the cow dung from cows grazing along the river, and found the same EHEC strain in the dung. So, when the rain washes away dung some of it ends up in the nearby river, and the amount was enough to infect persons eating the washed lettuce.

An epidemiologist would like to continue their search. Why do the cows not show symptom? From which source were the cows getting the EHEC etc. The chain can be traced further and further away.

The first step in the analysis is a narrow system boundary – the eaten food. In order to find the source of disease, the system boundary is widened to include the environment the food comes from. When that link is established, one could stop further work. But in order to make sure that the transmission is under control, the system boundary is widened even more to include animals.

When we talk about the source of pathogens or the origin of the disease, we must remember that the answer is not always final, but depends on at what system boundary you have decided is satisfactory and that you can contain further spread of the disease.

3.2–3



This example of a foodborne outbreak is easy to follow once the route of transmission has been discovered. The case illustrates several of the sanitation and health issues covered in this module.

A larger than usual number of EHEC infections was reported to the surveillance system and the health authorities realised that there was an outbreak. Great efforts were made to find the source, and nearly 60 people were involved in the investigation. Lettuce was found to be a risk factor in the epidemiological assessment, and finally one lettuce producer was identified as a source. It was noted that the producer irrigated their fields with river water. Water samples were collected and EHEC was found in the water. Bacteria isolated from stool (faecal) samples from patients were compared to the water samples and it was concluded that it was the same strain of the bacteria. Eventually run-off from agricultural land upstream of the producer's water source was identified as the cause of the outbreak. On this land, cattle were infected with EHEC and the bacteria were transported from the cow dung by surface run-off to the river water that was used for irrigation.

3.2–4

Transmission by animals

- **Zoonoses**
  - Transmission humans ⟷ animals
  - May cause symptoms or not in animal
- **Vectors**
  - Insects, rodents, birds – mechanical transport
  - Birds, wild and domestic animals infected without symptoms
- **Intermediate host**
  - Animal necessary for lifecycle of pathogen, e.g. malaria, schistosomiasis

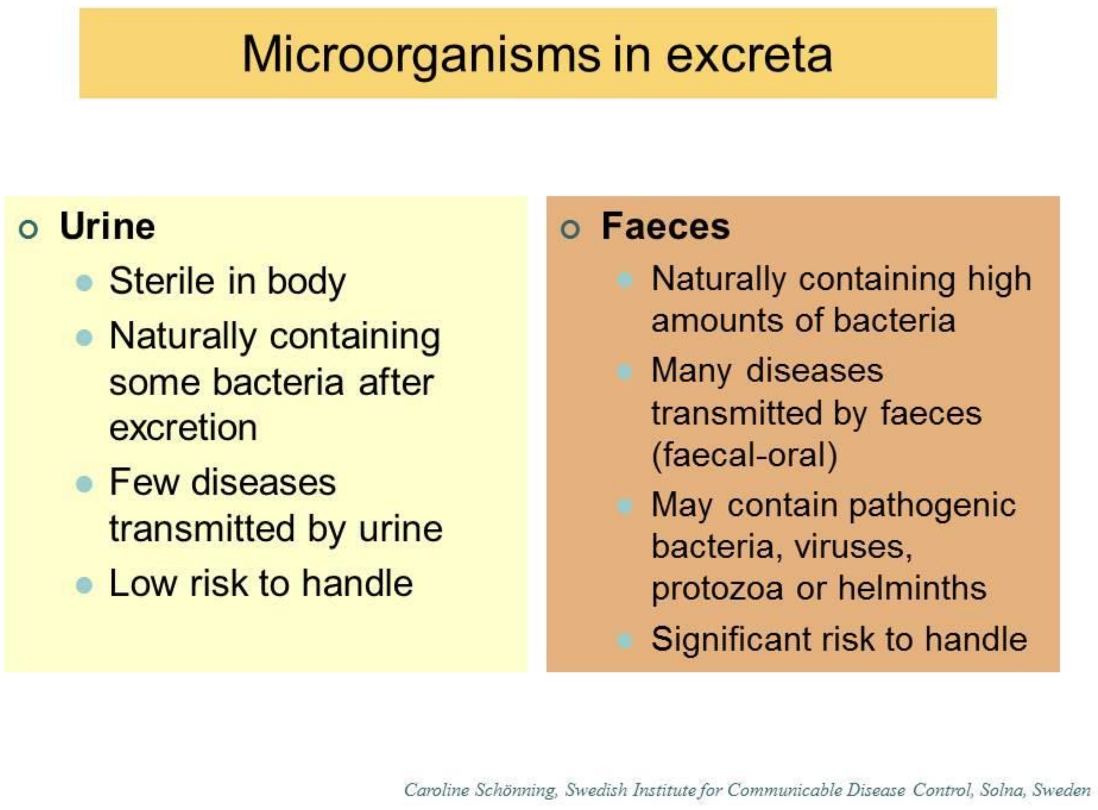
Caroline Schönning, Swedish Institute for Communicable Disease Control, Solna, Sweden

Infectious diseases that can be transmitted from animals to humans are called zoonosis. This possibility makes the environmental transmission routes of diseases more complex. The infections may or may not cause symptoms in animals.

Animals can also be vectors – animals that transmit diseases. Vector-borne transmission may occur by the mechanical transport of pathogens. Infected animals may move the pathogens to another location exposing humans (or other animals). Vectors are usually insects, rodents or birds. Examples of vectors are mosquitoes which transmit malaria, dengue fever and other diseases.

Some infections also require an animal host for further transmission. This is the case for schistosomiasis where eggs are excreted in urine or faeces and a specific freshwater snail is infected by the larvae after hatching (one of the life stages of the parasite). The aquatic larvae are then excreted in the water by the snail and have the potential to infect new human hosts.

3.2–5



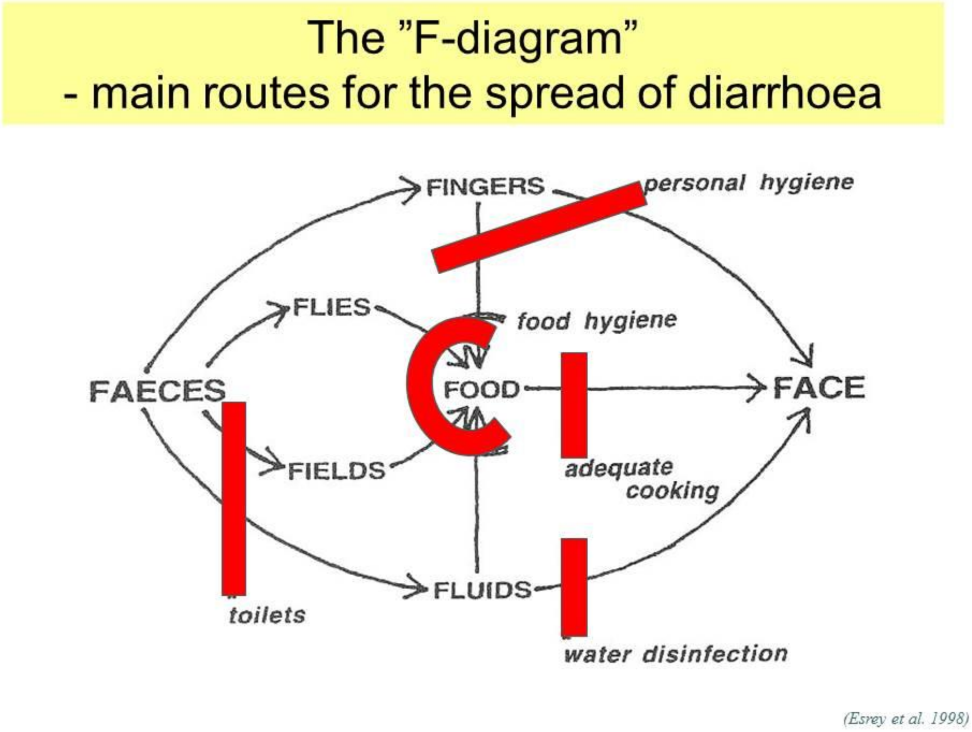
The picture above summarizes the health risks from urine and faecal matter. Urine poses low risks compared to faeces. It is sterile in the body of a healthy person. Only a few diseases are transmitted through urine. Faeces are different. They contain large amounts of naturally occurring, non-harmful bacteria, but many diseases are transmitted via the faecal-oral route and faeces commonly contain pathogens. Faeces should therefore be handled with caution.

Using urine as a fertiliser carries little health risks compared to untreated faecal matter. This is an important message since urine contains most of plant nutrients excreted by humans, and, therefore, is the most valuable fraction for reuse (see Chapter 4 about agricultural use).

If faeces are kept separate from other waste fractions, as is done in urine-diverting toilets, the other fractions can be used as fertilizers after some treatment, and the treatment and handling of the faecal fraction can be conducted in a safer and more optimized way. This is generally true both in high-tech systems and low-tech systems, and can result in the creation of sustainable systems regardless of whether financial resources for sanitation are scarce or plentiful.

A more detailed account of pathogens in faeces, urine, wastewater and sludge is now given.

3.2–6



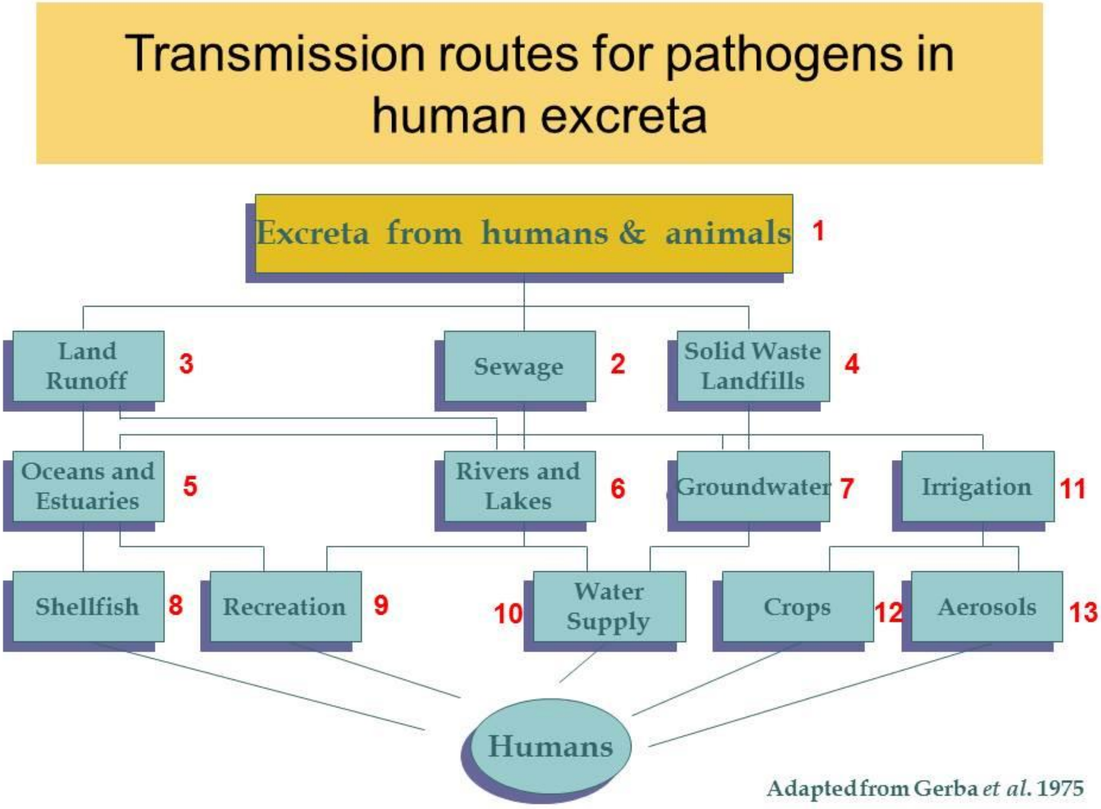
Extensive experiences of disease transmission gradually adds up to a situation where one can give hints on where to look for pathogen transmission routes and ways to block such routes, often by simple measures or barriers.

Faecal-oral transmission is the main route when it comes to sanitation, and therefore we focus on that here. Disease and various symptoms are dealt with in Module 3.1, and here the main/concern is diarrhoeal disease caused by gastrointestinal (enteric) infections via faeces or toilet wastewater. The F-diagram above is often used to describe the spread of diarrhoea in society. It shows how pathogens in faeces can reach the face and be ingested via fluids, food, flies and fingers. Fingers may carry pathogens if faecal material has been touched, e.g. when defecating, changing diapers or touching a contaminated surface like door handle or toilet knob.

The diagram is simple and instructive, and instead of requiring deep knowledge of pathogens it recommends simple actions to protect oneself from disease. The principle of barriers is valid for all sanitation systems – while the faecal material may be present in different forms.

In some societies child faeces are considered harmless, but many infections (like rotavirus) are more common among children so it is important to see everybody’s faeces as potentially harmful. It is also possible for an infected person to contaminate food that is then served to others. Proper hand washing after defecation and before eating is an effective barrier. Flies can physically transport microorganisms on their legs from faeces to food. By covering the food this route is blocked. The arrow from FIELDS → FOOD illustrates the risk of transmission if faeces from humans (or animals) are used as a fertilizer without proper pre-treatment before use, or if open defecation in fields is practised. The barrier is to end open defecation and to pre-treat organic fertilisers. Transmissions via fluids are illustrated by contaminated drinking water.

Urine may also contain pathogens, but to a much lesser extent (See slide 3.2-5).



3.2–7

Another systematic way of describing the transmission routes for pathogens in water and sanitation systems is by schedules/pictures such as the one above.

The enteric (meaning from the intestine) pathogens are excreted in human or animal faeces (1). The faeces either end up in sewage (wastewater) (2), on land (3) or in solid waste landfills (4). From all these sources pathogens can be transported to oceans and estuaries (5), rivers and lakes (6) or to groundwater (7). This water may then be used for growing of shellfish (8), for recreation (swimming) (9), as a water supply (for drinking water) (10) or for irrigation of crops (11, 12). It is possible for humans to ingest pathogens.by consuming crops, shellfish and drinking water. When swimming or performing other water-related activities water may unintentionally be swallowed. Sewage/wastewater may directly, or after some treatment, be used for irrigation of crops and apart from contaminating crops, pathogens may also be ingested by exposure to aerosols formed when irrigating the crops (13).

How such exposure and risks can be managed is further described in Modules 3.3 and 3.4.

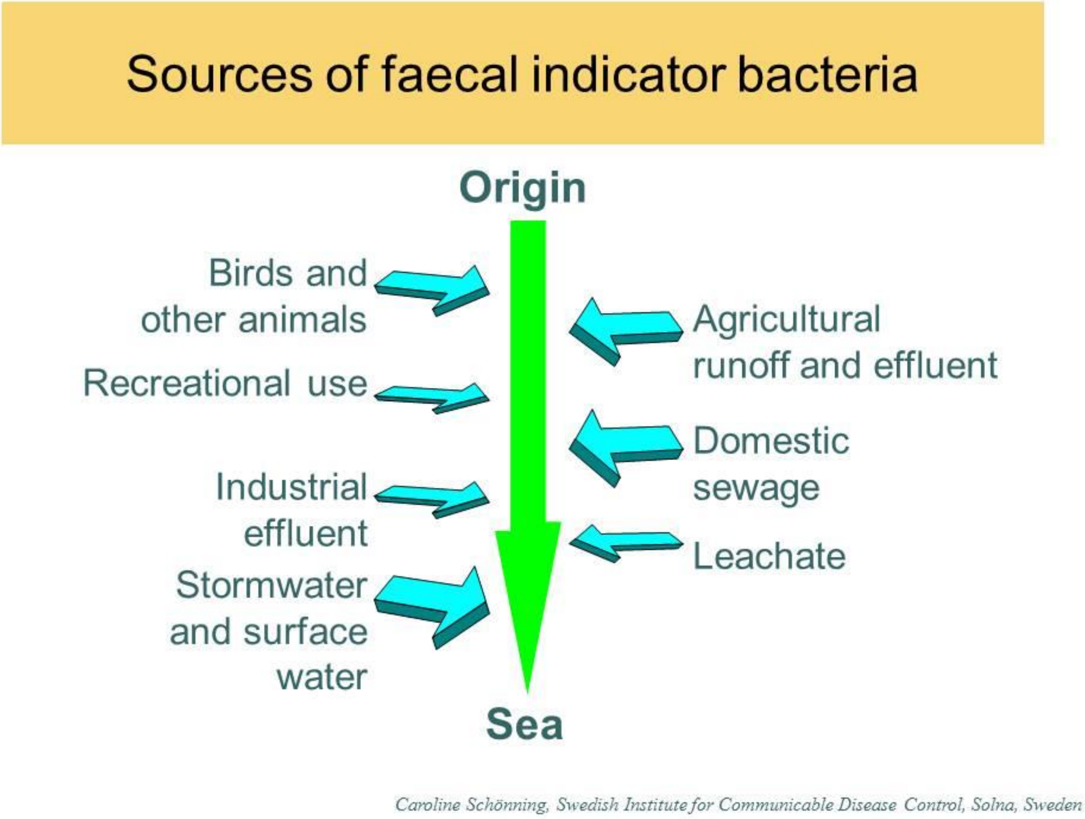
3.2–8

Pathogens in faeces

- May contain bacteria, viruses, parasitic protozoa and helminths that cause infections
- Diarrhoeal disease is the main concern
- Faeces should be considered a health hazard
- Need to be treated before use as a fertiliser
- Easier to handle and treat if diverted from other waste fractions

Caroline Schönning, Swedish Institute for Communicable Disease Control, Solna, Sweden

Infectious diseases can be caused by bacteria, viruses, parasitic protozoa and helminths and the main health risk in relation to sanitation systems is exposure to pathogens causing diarrhoeal disease. The majority of these pathogens are excreted in faeces and an infected person can excrete large numbers of pathogenic organisms. The prevalence of infectious diseases varies greatly between societies and populations. However, despite these variations, faeces should always be considered as harmful to health. Faeces should be handled with care and need to be treated before being used as fertilizer as discussed in Modules 3.3 and 3.4 and in Chapter 4. Exceptions exist where treatment of faecal matter is not necessary e.g. for growing of trees in shallow pits (like the Arbour Loo, see Chapter 5). A basic problem in waterborne sewage systems is the production of large volumes of contaminated wastewater that need to be treated, which for various reasons is not feasible everywhere (see Chapters 1 and 2).

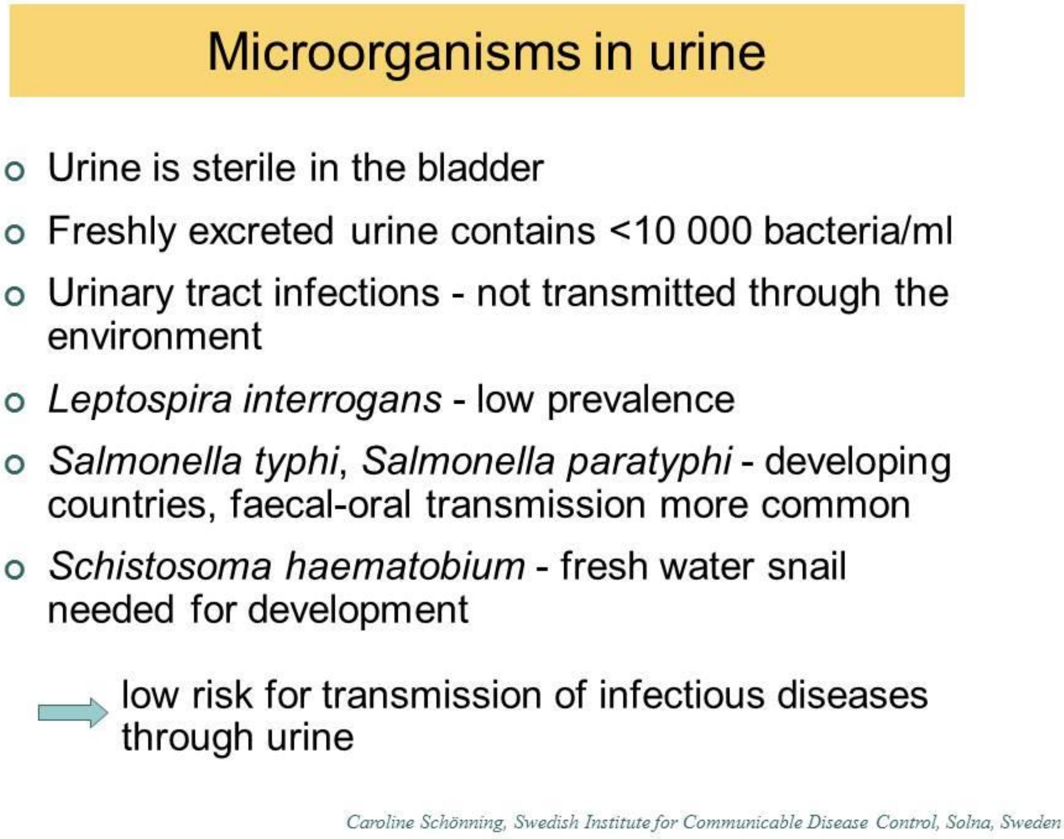


3.2–9

Faecal bacteria may originate from a variety of sources. As can be seen in the picture above, domestic (household) sewage is a major source of faecal bacteria together with agricultural, stormwater and surface water. Leachate is the liquid of contaminated water leaked from landfills. This is a general picture, and the local variations may differ a lot. Suffice it to know that pathogens are present in many flows, not only in domestic sewage.

Pathogens found in domestic sewage or faecal matter indicates the health conditions in a community. The presence of pathogens depends on what type of infections people have and how common these are – that is, they indicate the prevalence of an infectious disease in the population. Faecal indicators are further discussed in Module 3.4.

3.2–10



Does urine contain pathogens that could cause problems in relation to sanitation systems? Urine is a sterile liquid in the bladder, but when excreted it contains up to 10,000 bacteria per ml. urine. A person with urinary tract infection may have a much higher concentration, but these are not known to be transmitted through the environment.

There are a few other pathogenic bacteria and viruses that have been isolated from urine but the pathogens commonly known to be excreted in urine are *Leptospira interrogans*, *Salmonella typhi*, *Salmonella paratyphi* and the parasite *Schistosoma haematobium*. *Leptospira* is uncommon and the *Salmonellas* are only excreted in urine from individuals with typhoid and paratyphoid fever, which are rare diseases in developed countries. In developing countries, however, these infections are endemic but still faecal-oral transmission is the most common route of transmission.

This parasite requires an aquatic snail living in fresh water for its life-cycle. Also, the parasite is not infectious when excreted. It can thus be concluded that the risk for transmission of infectious diseases through urine is low.

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3.2–11

Origin of pathogens in wastewater - contribution from different waste fractions

- **Faeces**
  - the main source of pathogens that cause enteric infections
- **Urine**
  - only a few diseases transmitted through urine
- **Greywater**
  - e.g. laundry, washing diapers, from food stuffs
- **Industry**
  - abattoir, food industry (plant pathogens)
- **Storm water**
  - e.g. surface run-off – animal faeces

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A closer look at wastewater gives us an idea of the contribution of pathogens from different waste fractions. A healthy individual does not excrete pathogens in urine or faeces. However, symptom-free persons may well excrete pathogens. If an individual has an enteric (gastro-intestinal) infection, large amounts of pathogens may be excreted in their faeces and end up in the sewage. Only a few diseases are known to be transmitted through urine, while bacteria that cause urinary tract infections are not further transmitted in the environment.

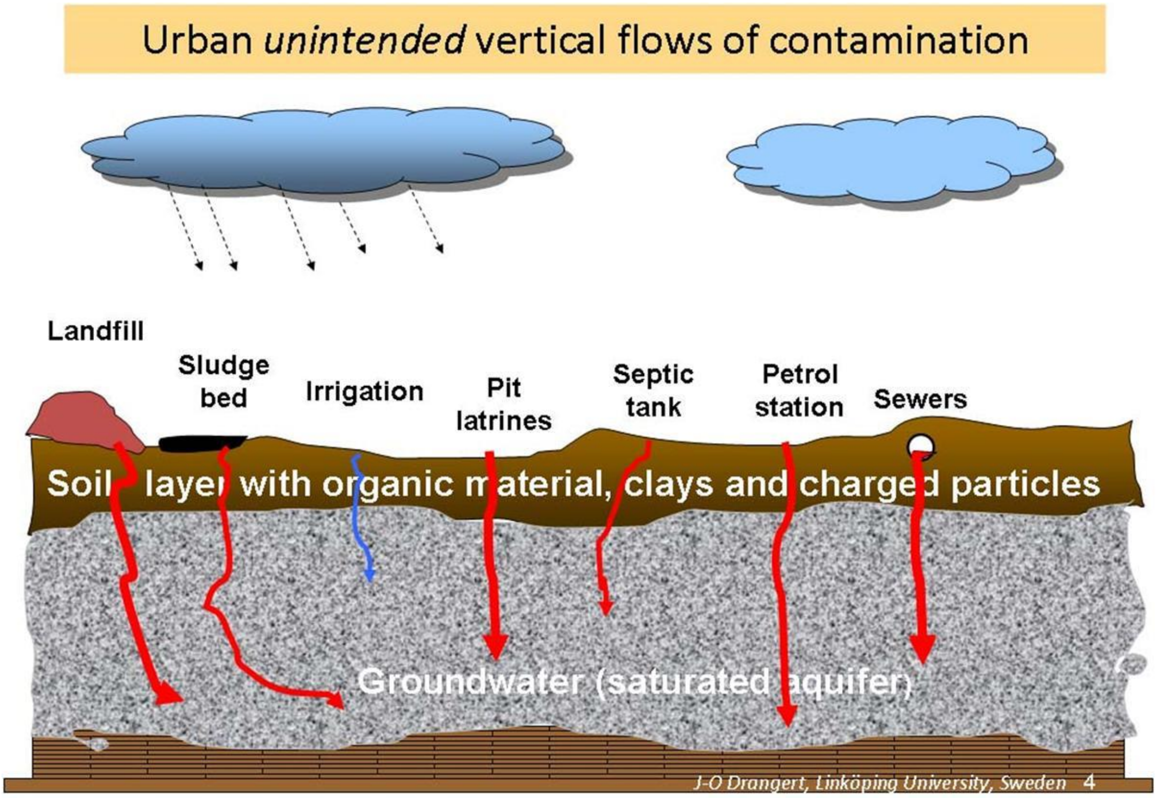
Greywater may also contain enteric (intestinal) pathogens, for example from laundry of soiled cloths, from showering and from washed foodstuffs in the kitchen sink. Symptom-less individuals and ill persons being treated at home also contribute pathogens to household (domestic) wastewater.

The contents of industrial wastewater depend on the type of industry. Regarding disease transmission, abattoirs and food industries are of concern, because they may contribute pathogens originating from plants.

Stormwater may contain pathogens e.g. from animal faeces that are transported by surface run-off. More details on the pathogens that can be present in different waste fractions are given both later on in this module and in Module 3.1.

Wastewater from hospitals is of special concern, but hazardous waste and hospital waste are outside the scope of this training material.

3.2–12



Drinking water is of particular concern since it is a necessity. It is estimated that 1 billion people do not have access to adequate drinking water. Preventing drinking water from being contaminated should be of utmost concern. Drinking water quality is affected by several factors, one of which is the presence of pathogenic microorganisms. Other health risks include the presence of chemical compounds such as nitrates, organic compounds and metals. In addition, some substances cause problems with bad smell or colour.

Drinking water is usually obtained from surface water or groundwater. Contamination of these sources may occur through run-off from latrines and land surface and from outlets of wastewater, both untreated and treated. Treatment of surface water is necessary in order to produce drinking water of acceptable quality.

The quality of groundwater is paramount when that is the main source of drinking water. This source is usually polluted in urban areas, often from unintentional events. The picture shows a number of ways that groundwater is being contaminated. Various contaminants are percolating with water down to groundwater (See Module 4.5). One often forgotten leachate is that from leaking wastewater pipes due to their poor state.

The goal of water treatment, usually of surface sources such as lakes, reservoirs or rivers, is to remove contaminants and organisms through a combination of biological, chemical, and physical processes to make it safe for drinking. Some of these processes occur naturally in the environment, whereas others occur in engineered and constructed water treatment plants. The engineered processes usually mimic or build on natural processes. Groundwater (e.g. from wells), on the other hand, is generally of better quality and is often used without treatment. This means that if groundwater sources are vulnerable to contamination, they become a serious health risk. There are no simple ways to treat groundwater in situ, and all treatment is done when it is available on the ground.

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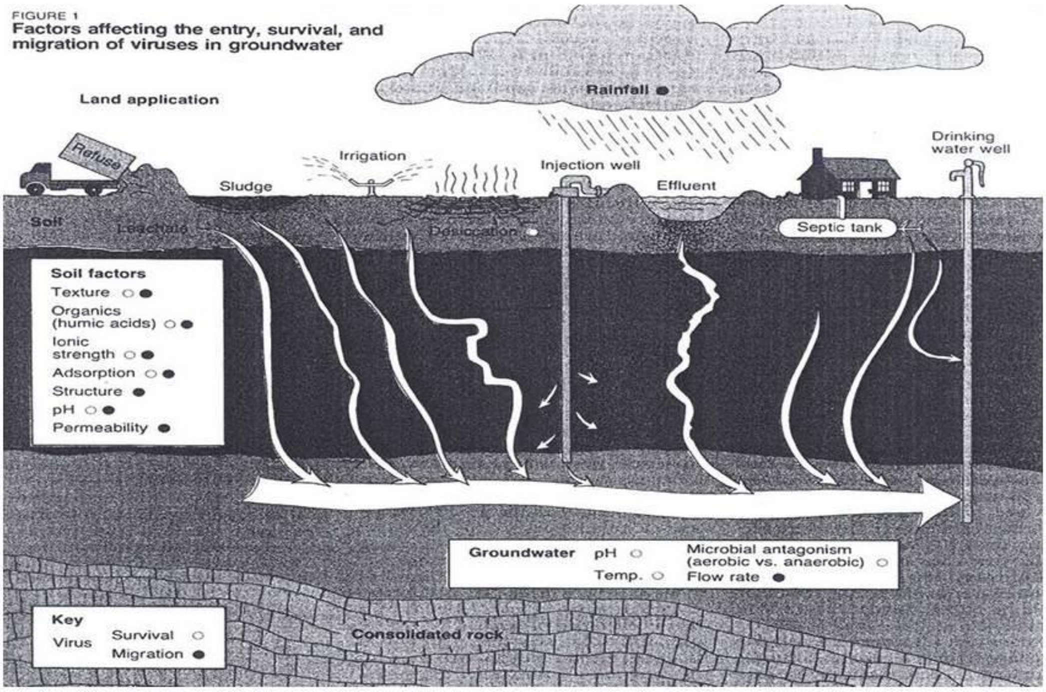
Contamination of groundwater

3.2–13



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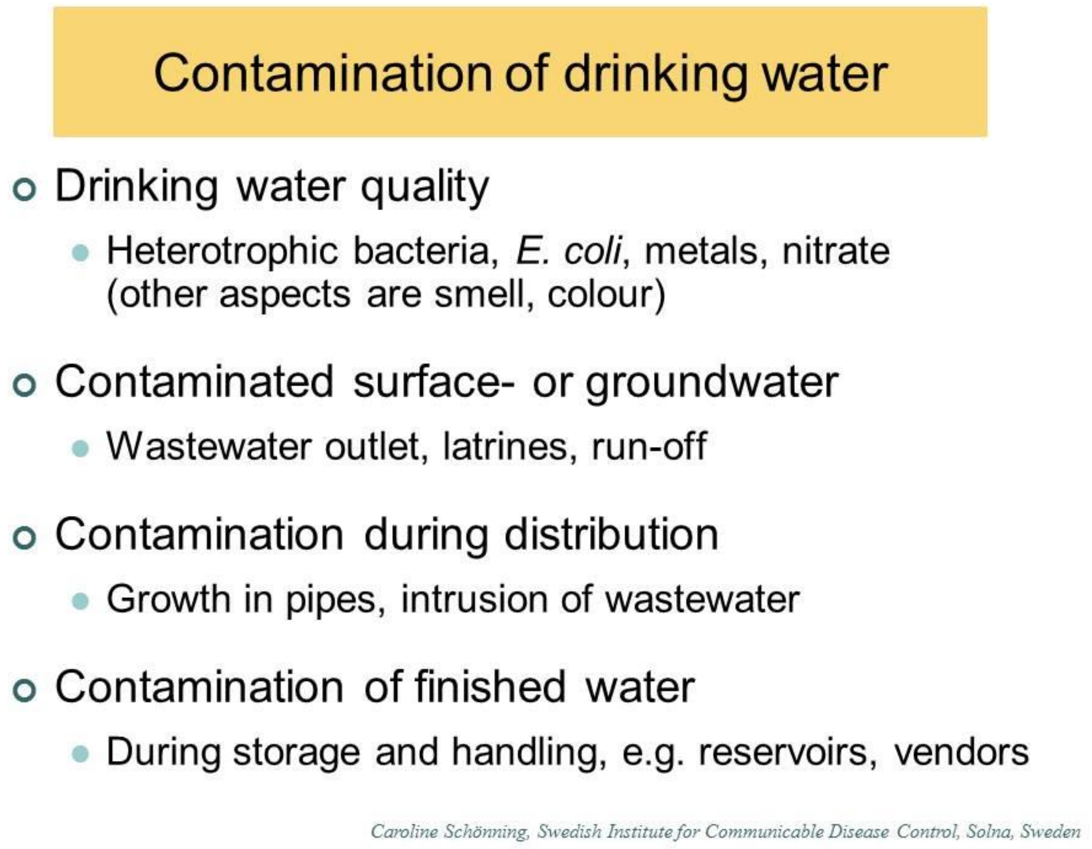
The above picture shows a peri-urban situation without piped water, with possible contamination from sources similar to those shown in the previous slide. Septic tanks often results in infiltration of wastewater that can contribute pathogens in groundwater. The risk of exposure to pathogens (and the risk of infection) from drinking well water will depend on the quantity of pathogens that reaches the groundwater and the bore hole or dug well. These factors will in turn depend on the types of organisms and soil type such as pH, structure, ionic strength and texture. Some of the organisms will be adsorbed to soil particles and some will reach the groundwater. Some of the organisms may also be inactivated (die) during the time of transportation through the soil to reach the groundwater. The survival of pathogens in the groundwater will also depend on conditions such as the pH and the temperature of the water.

One example is given of transport of microorganisms from latrines to wells in Eldoret town in Kenya where a study of groundwater was conducted. The wells were situated up to 40 metres from the pit latrines on level ground and were considered safe. The possible occurrence of contamination was tested by adding bacteriophages in the latrines as a tracer. Bacteriophages are viruses that infect bacteria, and in this case a type of phage was used that infects Salmonella and the phage does not exist naturally in the environment. Daily samples were collected from the wells and tested. After a few days phages were detected. This shows that pathogens, especially viruses, can be transported long distances in the soil – even in a flat landscape. The study concluded that not only the distance, but also the flow direction of groundwater and topography need to be considered when choosing places for wells and latrines (Drangert et al., 1996).

3.2–14



Microbiological quality of drinking water is often assessed by the presence of so-called indicator bacteria which include coliforms and E. coli. Guidelines from Ministries of Health issue values for maximum acceptable levels of indicator bacteria (Module 3.4). The main message when choosing a sanitation system is to select one that is likely NOT to reduce the quality of drinking water sources (as discussed in Chapter 2). For example, proper siting and depth of latrines (pits) and infiltration units is crucial for protecting the groundwater quality. Containment of faeces above ground is preferred. Surface water used for drinking water or recreation should be protected from wastewater discharge (outlets) and run-off from land where human or animal faeces can contribute pathogens. It is also necessary to avoid pollution of waterways (e.g. rivers) upstream of locations where they are used as water sources.

Contamination may occur both from transport of pathogens through the soil as described above and from poorly maintained hand pumps e.g. due to loose lids allowing intrusion of contaminated water.

Contamination may further occur during distribution of the drinking water in pipes. One important consideration is the need to keep pipes as intact as possible and with constant water pressure to prevent intrusion of wastewater during low pressure. Microbial growth on inner surfaces of pipes is inevitable, but should be controlled, ideally by distributing water with a low organic content and by the appropriate use of disinfecting chemicals.

Even if safe water is delivered to the household, contamination may occur during storage and handling, e.g. if the storage container is not clean, or if unclean hands touch the water, or if insects, birds or their droppings enter the container (e.g. if a proper lid is not attached). For drinking water (as well as for food) it is important that the whole chain from production to consumption is kept clean and safe.

3.2–15

Health risks related to untreated wastewater

- Local environmental pollution
  - Accidental exposure
- High risk of down-stream pollution
  - Exposure from e.g. swimming and intended household use
- Pollution of drinking water sources
  - Surface run-off and ground water infiltration
- Contamination of irrigated crops
  - Exposure during irrigation and at consumption

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The two previous slides show how contaminated water can percolate and negatively affect the groundwater quality. Also, surface water is contaminated.

The lack of proper waste and wastewater management, in addition to the lack of sanitation per se, results in health risks due to exposure to untreated or insufficiently treated wastewater. In poor peri-urban areas the most obvious sanitation problem is wastewater flowing on the ground or in so-called wastewater ditches (see picture). Direct contact with this water, especially for children, poses a significant risk for infection as a result of unintentional ingestion. Use of this water, or of streams polluted with such water, is often necessary and results in health risks through direct contact for people performing tasks such as washing clothes and cleaning or preparing food. In such areas the drinking water sources are often unprotected, e.g. an open shallow dug well may be used, and well water is easily polluted by surface run-off or by infiltration of wastewater.

The risk of crops being contaminated is high, and constitutes a health risk especially if the crops are consumed raw. The use of insufficiently treated faeces, and of other waste fractions, results in similar risks. There is also a risk of agricultural workers ingesting pathogens during irrigation and fertilization of the crops.

After this general description of transmission routes of various kinds, we take a closer look at the pathogens involved. Since there is a need to explain why certain barriers should be maintained, the following slides deal with more science-based information.

3.2–16

Excretion of pathogens in faeces

	Incidence (per 100.000)		Excretion (per g wet weight)		Duration (days)	
	Typically	Variation	Typically	Variation	Typically	Variation
Bacteria						
Salmonella	500	300-700	$10^{8.0}$	10^{4} - 10^{8}	37	25 - 55
EHEC	30	20-40	$10^{2.5}$	$10^{1.5}$ - $10^{3.5}$	8	5 - 13
Viruses						
Rotavirus	1200	800-1600	$10^{9.0}$	10^{7} - 10^{11}	5	0,5 - 60
Hepatitis A	6	(4-8)	$10^{5.0}$	10^{4} - 10^{6}	20	12 - 33
Parasites						
Giardia	1100	900-1300	$10^{6.5}$	10^{5} - 10^{8}	90	22 - 365
Cryptosporidium	200	150-250	$10^{7.5}$	10^{7} - 10^{8}	7	1 - 40
Ascaris	20	14-26	$10^{4.0}$	$10^{3.5}$ - $10^{4.5}$	245	90 - 665

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Depending on the kind of infection a person has, varying amounts of pathogens are excreted in the faeces. The examples listed in the above table illustrate the variations between different pathogens, but also between infected individuals.

The incidence of pathogens found in faecal matter excreted among 100 000 person or stool samples, varies from a few (Hepatitis A) to over a thousand (Rotavirus and Giardia). This represents the prevalence of sick people in an average population.

The variation in the number of pathogens in a gram of wet faecal matter in infected persons is very large in most cases. For example, there are up to 10 000 000 000 rotaviruses (ten billions or equal to the number people on the globe in the year 2050) and 10 000 Ascaris eggs. The infectious doses, i.e. how many microorganisms that is required to cause infection also varies depending on infection, and on the individual who is exposed.

The number of days (duration) an infected individual excretes a certain pathogen varies considerably: from a few days to years. Some infections may even be chronic, in which case excretion of the pathogen is life-long. Numbers can also vary during the course of an infection with higher numbers in the first (acute) phase of the illness. And in many locations with bad sanitary conditions it is not uncommon for most people to be infected with one or more gastrointestinal infection. Exposure is imminent in such areas.

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3.2–17

Pathogens in urine and importance of urine as a transmission route

Pathogen	Urine as a transmission route	Importance
Leptospira interrogans	Usually through animal urine	?
Salmonella typhi and *Salmonella paratyphi*	Probably unusual, excreted in urine if systemic infection.	Low compared to other transmission routes
Schistosoma haematobium (eggs excreted)	Not directly but indirectly, larvae infect humans in fresh water	Need to be considered in endemic areas where freshwater is available
Mycobacteria	Unusual, usually airborne	Low
Viruses: CMV, JCV, BKV, adeno, hepatitis	Not recognised other than single cases of hepatitis A and suggested for hepatitis B	Low
Microsporidia	Suggested, but not recognised	Low
Venereal disease causing	No, do not survive outside the body	-
Urinary tract infecting	No, no environmental transmission	-

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A summary of pathogens possibly transmitted in urine and the importance of urine as a transmission route for each of these pathogens is presented in the table above.

As stated in a previous slide *Leptospira interrogans* is known to be excreted in urine. There are, to the authors' knowledge, no reports of this disease being contracted from human urine. It is more common to refer to it as a potential risk from animal urine (e.g. from rats). Typhoid fever is a large problem in developing regions and the bacteria can be excreted in urine, but we consider the importance of it as a transmission route as low. Mycobacteria can be found in urine but this infection is usually airborne.

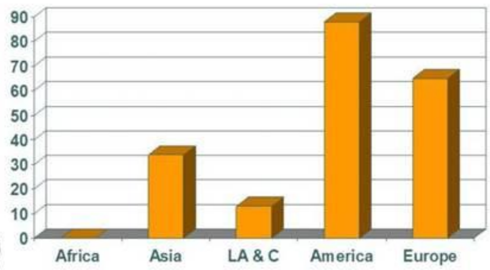
It has been suggested that the parasitic protozoa *Microsporidia* is transmitted via urine but it is (so far) not a recognized route. Venereal diseases may be thought of as a concern related to sanitation, but the organisms causing such diseases are not relevant since they are not adapted to environmental conditions outside the body and their transmission occurs from person to person when they are "exchanging" bodily fluids. Urinary tract infections (UTIs or urethritis) are common but are not caused by environmental transmission. Urethritis occurs when bacteria, usually from your rectum, travel into your urethra and grow there. Bladder infection, or cystitis, occurs when bacteria travel up past the urethra and lodge in the bladder. Bladder infections are the most common form of urinary tract infection, and can often occur at the same time as urethritis. *E. coli* is the most common cause of urinary tract infections.

The risk of disease transmission from urine itself is negligible. However, possible faecal cross-contamination – that is, faecal matter that is misplaced in a urine-diverting toilet – can be a route of contamination. Quantification of this faecal contamination is further discussed in Module 3.5.

3.2–18

Pathogens in mixed wastewater

- Small volumes of faeces contaminates large volumes of clean water
- Collection from a large number of persons – pathogens continuously present
- Smaller systems – higher concentration of a specific pathogen
- Treatment not optimized for killing pathogens
- 10% of wastewater is treated (developing countries)
- 20 million ha (?) irrigated with wastewater



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When water-flush toilets are used, small amounts of faeces contaminate large volumes of more or less clean water. In large sanitation systems (in which many people are connected to the same system) a large variety of pathogens will be continuously present since it is likely that someone connected to the system has the infection in question. In smaller systems it is less likely that a specific pathogen will be present at any given time but during events of infection, or during outbreak situations, the concentration of a pathogen may be higher than in a large sanitation system, resulting in a significant risk if people are exposed to the wastewater or sludge.

Where wastewater treatment plants are in place, the sewage/wastewater is treated in various processes that are categorized either as mechanical, biological or physical.

However, the treatment plants are not optimized for reducing (killing) pathogens. The concentration of pathogens in outgoing wastewater varies a lot and is dependent on the type of pathogen and the type of treatment process(es). It is only a final disinfection step that can effectively remove pathogens by killing them. It is therefore very important that the outlets from treatment plants are located in places where the harm to recipients and exposure to humans are minimized.

Treatment and barriers to hinder disease transmission is further discussed in Module 3.3. For details regarding the treatment of mixed wastewater, further reading of specialized text books is recommended (examples are given at the end of Chapter 3).

It is also important to remember that worldwide, only a small fraction of sanitation systems producing wastewater are connected to wastewater treatment plants. In many developing countries, the bulk of domestic and industrial wastewater is discharged without treatment or after primary treatment only and it is estimated that only 10% is treated effectively. The graph above shows estimates for the percentage of wastewater that is treated in various parts of the world.

3.2–19

Pathogens in greywater

- Lower concentrations of pathogens here than in faeces
- Faecal origin of pathogens (bathroom and laundry)
  - Shower and bath, washing clothes, washing diapers
- Pathogens from food stuffs (kitchen sink)
  - Faecally contaminated vegetables (e.g. from irrigation with wastewater or application of animal manure), soil
  - Contaminated meat (e.g. chicken)
- Health risk from disposal or reuse
  - Contamination of nearby surroundings
  - Contamination of drinking and recreational water
  - Irrigation of crops

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In addition to urine and faeces, households produce greywater. Greywater systems, from collection to treatment and possible reuse, may vary a lot in design and management. Greywater is dealt with in detail in Chapter 4. The content of greywater depends on what flows are collected from the household and what products (chemicals etc.) are used. Pathogens are generally present in greywater, but the concentrations are much lower than in faeces or in mixed wastewater containing faeces. Greywater may however be high in nutrients that bacteria can thrive on, resulting in possible growth of bacteria. This has proved to be the case for indicator bacteria (see Module 3.3).

Faecal pathogens in greywater can come from dirty laundry (underwear), washing of diapers or showering/bathing. Different foodstuffs can also contain pathogens, due either to faecal contamination (e.g. from wastewater irrigation or animal manure) or to "internal" contamination that occurs during production. For example, Campylobacter are present in 30% of chicken retail products in the Netherlands.

Health risks from greywater are similar to those associated with mixed wastewater – that is, potential pollution of nearby surroundings, pollution of recreational waters and drinking water sources. Greywater is used for irrigation of crops mainly as a water source, not for its nutrient content. Health risks have been recognized and are further described in Module 3.4 and in Chapter 4.

3.2–20

Typical concentrations of microorganisms in sludge (EC, 2001)

		[per g wet weight]
Bacteria	*E coli*	10^6
	Salmonella	10^2-10^3
Virus	Enterovirus	10^2-10^4
Protozoa	*Giardia*	10^2-10^3
Helminths	*Ascaris*	10^2-10^3
	Toxocara	10-10^2
	Taenia	5

When treating wastewater, pathogens are being concentrated in the sludge – not in the effluent

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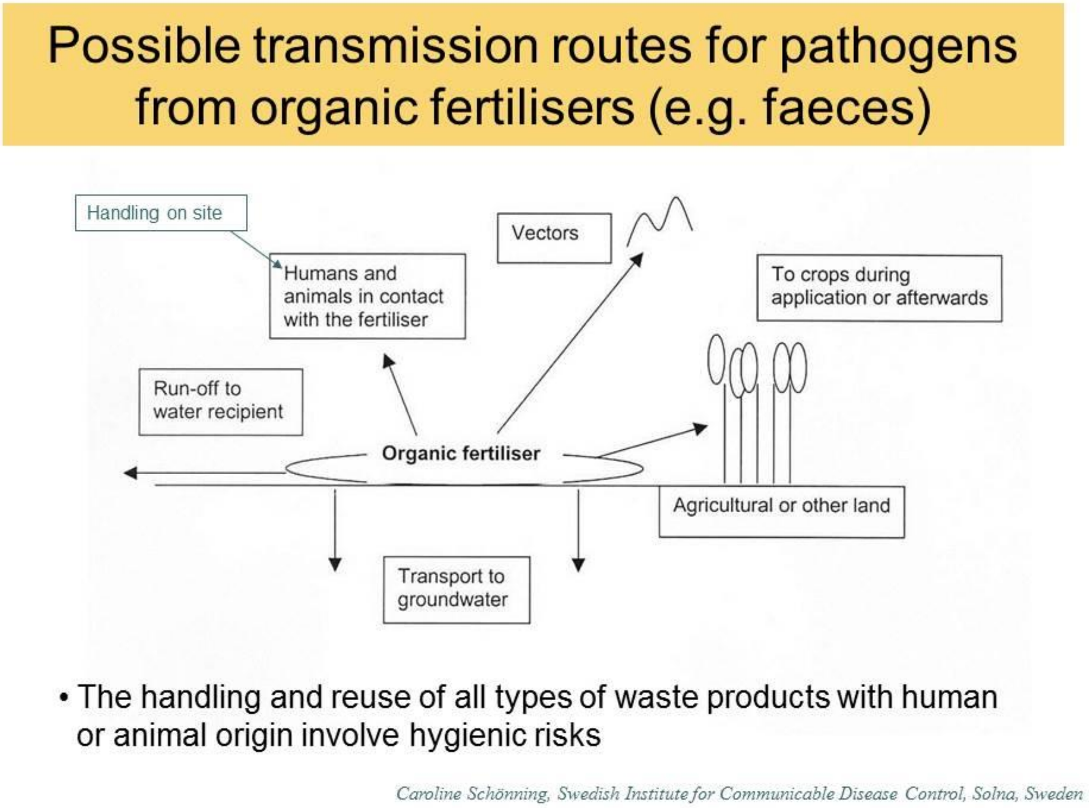
In any wastewater treatment, sludge is produced. Since pathogens in wastewater are attached to particles, pathogens will be concentrated in sludge and not in the effluent. The table above shows typical concentrations of the indicator *E. coli* and some other pathogens that can affect human and animal health. Since sludge also contains nutrients it is used as a fertilizer in agriculture. In many countries sludge is treated before use (hygienization) in order to decrease the risk of disease transmission. But regulations vary and other barriers may be introduced to decrease exposure (see Module 3.3).

Sludge is also formed in single-household systems e.g. septic tanks. A concentration of pathogens occurs, and the material can, in terms of some of the associated risks, be comparable to faeces. However chemical pollution of both wastewater and sludge is of greater concern.

3.2–21



Reuse of "waste products" containing plant nutrients is encouraged in Chapter 1. Fertilizer products such as wastewater, sewage sludge, animal manure, human urine, treated faeces or organic household waste (food waste) may be used.

The use of organic waste fertilizers will always involve some risk of humans and animals being exposed to pathogens. Exposure can occur during the handling of the material, since there is a risk of accidental ingestion for a person coming into direct contact with pathogens. Direct contact is also possible after application. Further spread of pathogens to the surrounding environment and waters and to crops may result from exposure by ingestion, e.g. when drinking the water, during swimming or when consuming food crops.

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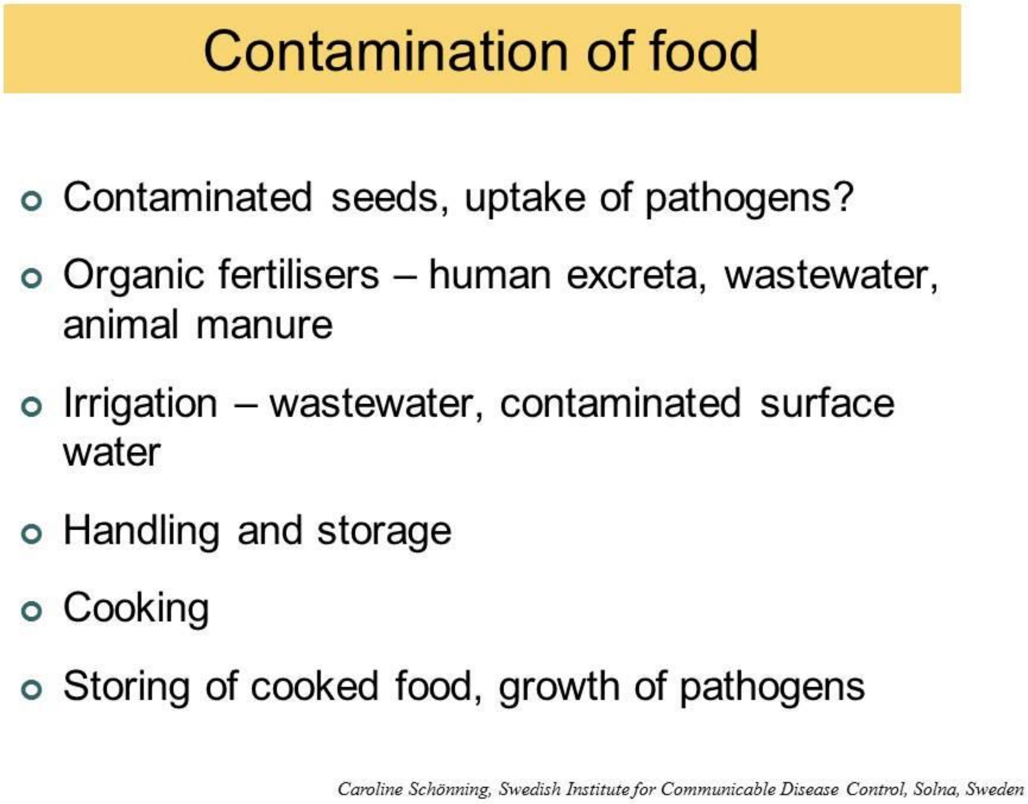
3.2–22



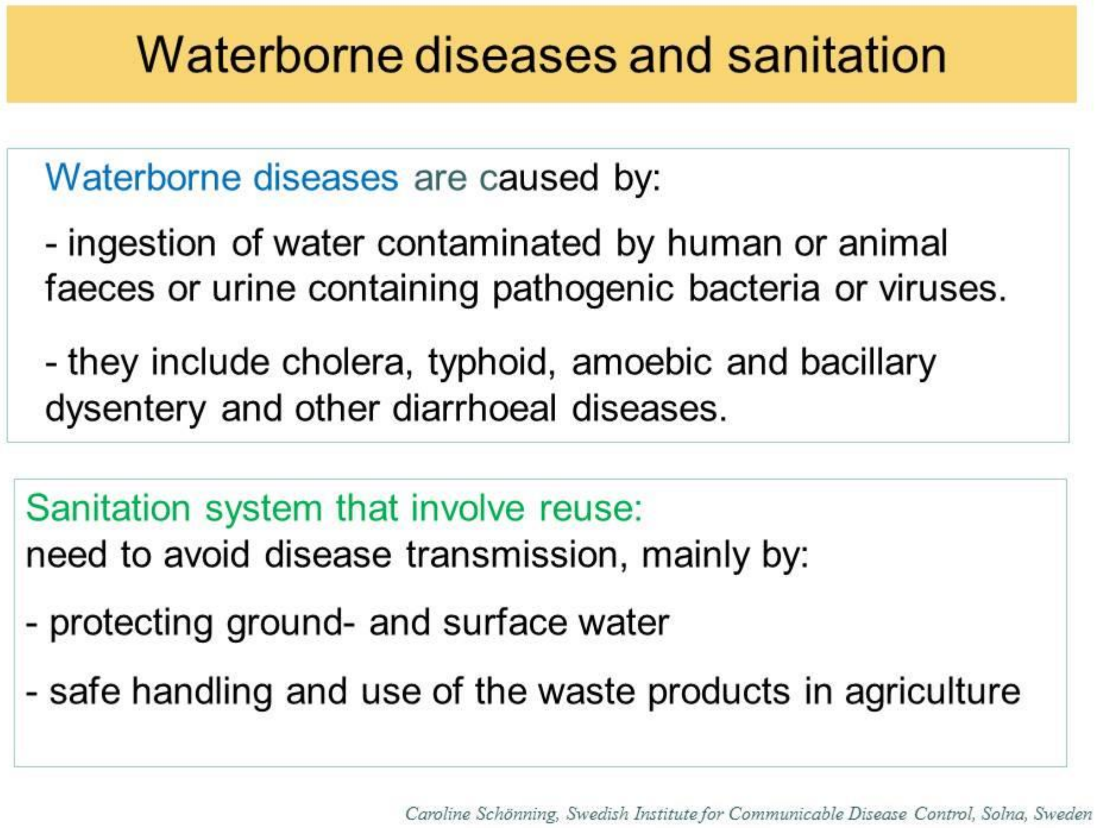
As is the case with drinking water, food may be a potential source of pathogens. Pathogens may be present from the beginning and in the crop if seeds are contaminated, but this risk is considered quite low. Fertilizer products from human (and animal) waste could add pathogens to the crop, as could wastewater or contaminated surface water that is used for irrigation. Later in the food chain it is possible that food may become contaminated by improper handling and storage, for example if hand hygiene is insufficient or if animals or insects come in contact with the food.

It is also common that raw food is contaminated in other ways. For example, meat or eggs can become contaminated in the production process. Some bacteria can grow on food, resulting in their presence in high numbers and potential infection by eating. Others produce toxins that are not removed by normal cooking procedures. Gastrointestinal disease caused by infection or a toxic reaction after food consumption is generally referred to as food poisoning. In general, pathogen risks are possible to manage, as described in subsequent modules, whereas chemicals cannot be removed from food or water as easily (in analogy with the example of bacterial toxin).

When discussing the reuse of waste products as fertilizers we are dealing with cereal, vegetable and fruit crops. Animal products like fish and meat may also contain pathogens that infect humans when they are consumed. Appropriate handling and proper cooking is essential to minimize these risks.

Health aspects related to aquaculture are not specifically included in this training material but further information on guidelines for irrigation and fertilization of crops is given in Module 3.4.

3. 2–23



As described in Module 3.1 water-related diseases can be divided into several categories. As stated, in this training material we deal mainly with the first group – waterborne diseases. The origin of the pathogens causing disease is human or animal faeces or urine. Waterborne diseases are of concern in relation to sanitation in all regions, whereas many of the other water-related diseases mainly are related to tropical areas around the world. But, the risk in a sanitation system is also related to other waste fractions. This training material covers the reuse of various waste fractions in agriculture, and so it deals not only with the potential exposure to pathogens in water, but also with possible exposure through the ingestion of crops that have been in contact with contaminated water or waste products.

According to the International Water Management Institute (IWMI) and the International Development Research Centre (IDRC) untreated wastewater is increasingly being used for irrigation in urban and peri-urban agriculture, and even in distant rural areas downstream of the very large cities, as a result of both increased amounts of wastewater and of water scarcity. The current knowledge about the amounts of wastewater used in various countries (Scott, Faruqui and Raschid-Sally, 2008) . This book also discusses the accuracy of the estimate that 20 million ha of the world’s agricultural land is being irrigated with wastewater.

Further reading:

For more information on drinking water quality guidelines we refer to the WHO (www.who.org). The new edition of the guidelines can be found at:

http://www.who.int/water_sanitation_health/dwq/GDW7rev1and2.pdf

Scott, C., Faruqui, N., and Raschid-Sally (2008). *Wastewater use in irrigated agriculture*. Confronting the Livelihood and Environmental Realities.

http://www.cabi.org/bookshop/book/9780851998237

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