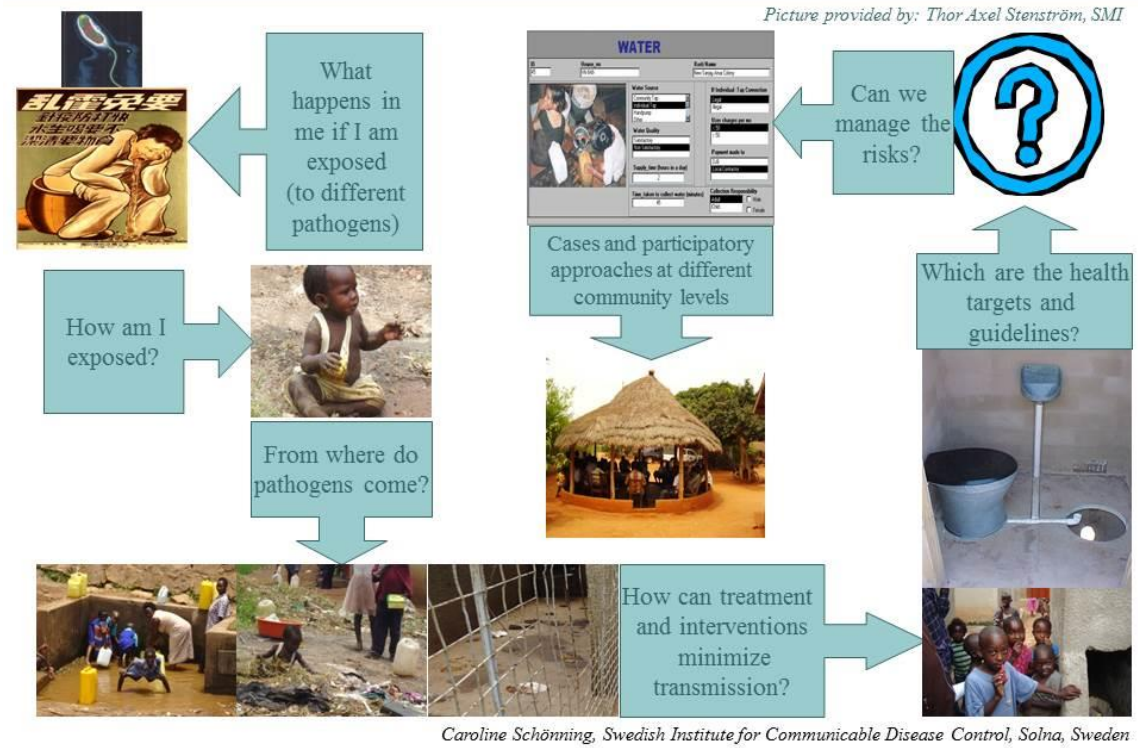
Chapter 3. Sanitation and public health



This chapter deals with the public health aspects of sanitation. The focus is on disease-causing microorganisms and how risks can be reduced. The picture above illustrates the transmission of disease from pathogens in the environment. It deals with exposure and potential effects on humans.

Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces. The word ‘sanitation’ also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal (WHO, 2010). Inadequate sanitation is a major cause of disease worldwide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities.

Around 1.1 billion people globally do not have access to improved water supply sources whereas 2.4 billion people do not have access to any type of improved sanitation facilities. About 1.5–2 million people die every year due to diarrheal diseases. Most of them are children less than 5 years of age. The most affected populations are in developing countries, living in extreme poverty, usually in peri-urban or rural areas. Among the main problems which are responsible for this situation are: lack of priority given to the sector, lack of financial resources, lack of sustainability of water supply and sanitation services, poor hygiene behaviours, and inadequate sanitation in public places including hospitals, health centres and schools. Providing access to sufficient quantities of safe water, the provision of facilities for a sanitary disposal of excreta, and introducing sound hygiene behaviours are essential to reduce the burden of disease caused by these risk factors. (WHO, 2010).

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This chapter deals with the risk of spreading of infectious diseases in sanitation systems and how these risks can be managed with proper facilities, handling and behavior. The importance of sanitation and the wide perspective that is needed can be understood by the following facts given by WHO:

- Examples of diseases transmitted through water contaminated by human waste include diarrhea, cholera, dysentery, typhoid, and hepatitis A. In Africa, 115 people die every hour from diseases linked to poor sanitation, poor hygiene and contaminated water.
- Studies show that improved sanitation reduces diarrhea death rates by a third. Diarrhea is a major killer and is largely preventable. It is responsible for 1.5 million deaths every year, mostly among under-five children living in developing countries.
- Adequate sanitation encourages children to be at school, particularly girls. Access to latrines raises school attendance rates for children. An increase in girls' enrolments can be attributed to the provision of separate, sanitary facilities
- Hygiene education and promotion of hand washing are simple, cost-effective measures that can reduce diarrhea cases by up to 45%. Even when ideal sanitation is not available, instituting good hygiene practices in communities will lead to better health. Proper hygiene goes hand-in-hand with the use of improved facilities to prevent disease.
- The economic benefits of sanitation are a persuasive. For every US$ 1 invested in improved sanitation, it shows an average of US$ 9 return in value. Those benefits are experienced specifically by poor children, and in the disadvantaged communities that need them most
- The Millennium Development Goals target 75% global sanitation coverage by 2015. The cost to reach the milestone is estimated at US$ 14 billion annually through the period. Among other health gains, sanitation is estimated to reduce diarrhea cases by 391 million worldwide each year

http://www.who.int/features/factfiles/sanitation/facts/en/index9.html

Module 3.1 includes facts and figures related to sanitation and infectious diseases, and explains basic epidemiology and burden of disease terminology**.** In Module 3.2 we describe how pathogens are spread in the environment through sanitation systems, resulting in a potential threat to humans and animals. Module 3.3 provides a theoretical and practical background to how pathogens can be eliminated, thus reducing the risk of disease transmission. More practical advice and rules of thumb for treatment of excreta are given in Chapter 4. Module 3.4 deals with health targets and guidelines, including theoretical information on faecal indicators and microbial risk assessment (MRA) that are directly linked to these risk management tools. Module 3.5 provides an overview of risk management, including a few examples of quantitative risk assessment (QMRA) and epidemiological studies.

In addition to sanitation as such, the chapter discusses the sustainable use of "sanitation products" or "waste products", such as treated excreta, in agriculture.

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3.1 Exposure and effects in humans

How are infectious diseases transmitted?

What happens when people are exposed to pathogens?

Learning objective: to become familiar with the most important pathogens found in water and sanitation systems, with the symptoms they cause and with their effect on individuals and populations.

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Microorganisms are a natural part of our environment and our bodies, and they are necessary for our survival and health. However, the harmful ones, known as pathogens, may cause disease and/or death if we are exposed to sufficient amounts. Exposure can either occur in the environment or through direct contact with other people or animals. In this module the exposure to pathogens and the effects of pathogens on humans are addressed in a general manner. Pathogens of concern in sanitation systems are described, with some details given, but further reading of relevant fact sheets is encouraged. The effect that sanitation is considered to have on public health on a global scale is also discussed. We introduce a standard terminology that will facilitate the presentations in the Sourcebook.

3.1 - 3

DALYs – a general measure for health

The Global Burden of Disease (GBD)
Murray and Lopez, 1996

- Disability Adjusted Life Years (DALY)
  - morbidity: years lived with a disability
  - mortality: years lost
- DALY (loss of healthy lived years) = n x t x S
  - n = number of affected persons
  - t = the duration of the health effect
  - S = measure of the severity of the health effect (mortality = 1)

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A large number of publications address the burden of disease, a concept that was originally introduced the report by Murray and Lopez in 1996 *(The Global Burden of Disease* (GBD)) in which they developed the indicator, Disability Adjusted Life Year (DALY).

Disability Adjusted Life Years (DALYs) are a measure of the health of a population, or of the *burden of disease* caused by a specific disease or risk factor. DALYs are used to measure, using one indicator, the total time that is lost due to the combined effects of ill-health, disability and early death. A DALY includes the time lost due to the acute stage of a disease (e.g. from being ill for one week), plus the time lost due to disability (reduced ability due to the disease) and the time lost due to premature death. DALYs are calculated by adding the years lost due to the acute incident, premature death and the years lived with a disability. Years lost are calculated by using age-specific mortality rates and the expected length of life in a given population. Years lived with a disability are calculated by multiplying the number of cases by the average duration of the disease and a *severity factor* that varies between 1 (death) and perfect health (0) and is dependent on the disease. Watery diarrhea, for example, has a severity factor between 0.09 and 0.12, depending on age group. DALYs is an important tool for comparing health effects since it considers acute, later developing and chronic effects, and includes both morbidity and mortality. It also makes it possible to compare different types of health effects, e.g. cancer compared to giardiasis, and this can aid in risk management.

DALY is a health gap measure that extends the concept of potential years of life lost due to premature death (PYLL) to include equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability. The DALY combines in one measure the time lived with disability and the time lost due to premature mortality. One DALY can be thought of as one lost year of 'healthy' life and the burden of disease can be seen as a measurement of the gap between current health status and an ideal situation where everyone lives into old age free of disease and disability. For relating to this information it is however only necessary to know that it is a measure (a unit) that can be used to understand the magnitude of the impact various risk factors have on public health.

Disease burden related to cases of disease vary widely in different localities, and DALYs can be used as a measure of these variations. For example, the disease burden per 1000 cases of rotavirus diarrhea is 480 DALYs in low-income regions, where child mortality frequently occurs. However, it is only 14 DALYs per 1000 cases in high-income regions, where hospital facilities are accessible to the great majority of the population. Many diseases are linked to starvation since malnutrition affects individuals' immune systems and infections manifest more easily if the immune system is suppressed.

Further reading:

The Global Burden of Disease (GBD) provides systematic epidemiological estimates for an unprecedented 150 major health conditions. It explains methods and presents results, including: disaggregated death and disability data; projections to the year 2020; and risk factor evaluations. While it minutely examines causes of death, the GBD is unique in its inclusion of disability. The authors explore the technical bases and moral implications of incorporating social, physical, and mental disabilities in health assessments, explicating the indicator they have developed, the disability-adjusted life-year (DALY). The GBD provides indispensable global and regional data for health planning, research, and education.

http://whqlibdoc.who.int/publications/2008/9789241596435_eng.pdf

http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(08)60925-3/fulltext?version=printerFriendly

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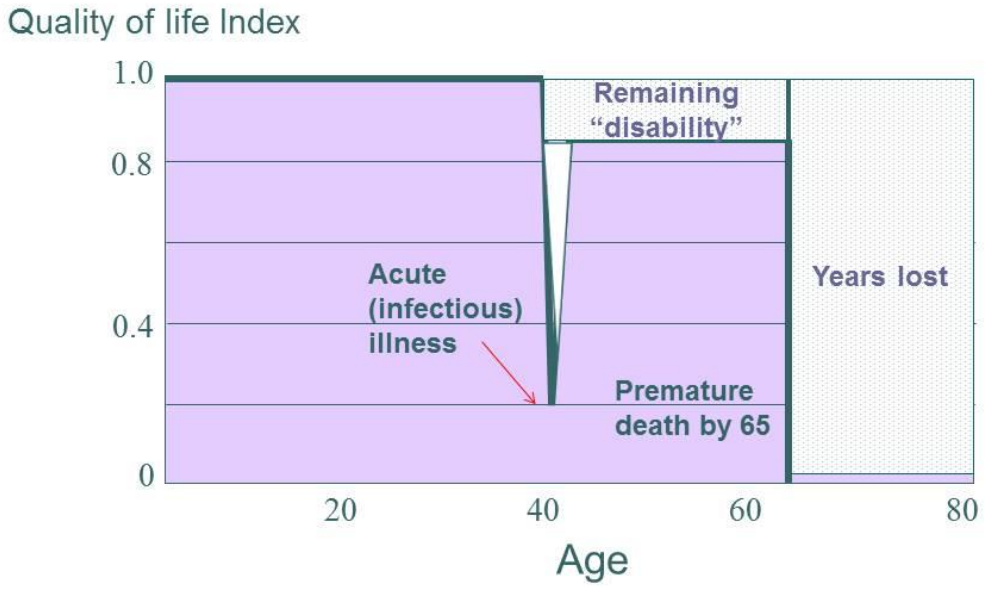
Hypothetical example of DALYs

3.1 - 4



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This is an example of how DALYs could be calculated for an individual. At age 40 a person suffers from an acute illness. The person recovers but is left with a disability corresponding to a severity factor of 0.1(seen as the dotted (grey) area between 1.0 and 0.9 up to the age of 65). As a result of the illness he then dies at 65 instead of the predicted 80 in the population, resulting in 15 years lost.

The total DALY for this individual (this case of infection) is thus (1 x 25 x 0.1) + (1 x 15 x 1) + the acute phase (exact time not identified), since n=1 person, t=25 years for the disability with S=0.1 and t=15 years for mortality (S=1). This corresponds to the formula in the previous picture, adding three time periods with different severity factors.

In quantitative microbial risk assessments DALYs can be included as a final step to present results for the assessment (see Module 3.4) but the definition is mainly given here in order to explain the factors included when assessing the health impacts of sanitation.

Leading DALYs in in the world 1990 & 2020

3.1 - 5

Murray *et al.* (1996) Science 274:740-743

Disease/Injury	1990		2020	
	Rank	%DALYs	Rank	%DALYs
Lower respiratory	1	8.2	6	3.1
Diarrhoeal	2	7.2	9	2.7
Perinatal period	3	6.7	11	2.5
Depression	4	3.7	**2**	**5.7**
Heart disease	5	3.4	**1**	**5.9**
Tuberculosis	7	2.8	7	3.1
Road accidents	9	2.5	**3**	**5.1**
HIV	28	0.8	10	2.6
Lung cancers	33	0.6	15	1.8

"The sanitary revolution" - the most important medical milestone since 1840 !? (BMJ, 2007)

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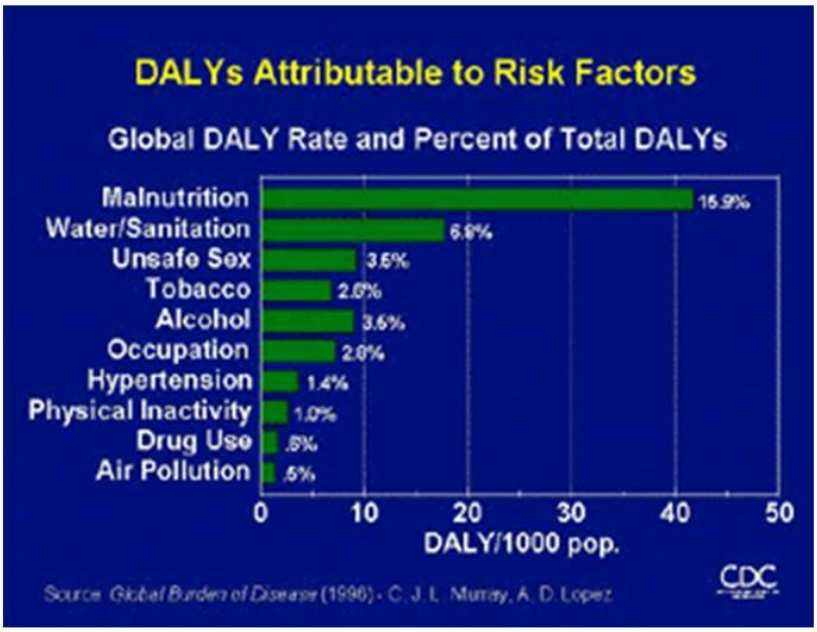
The above table shows the rank of some diseases and injuries and the expected future global situation. It is anticipated that what can be called (economic) development will result in an increase in heart disease (e.g. due to changes in food intake), depression and road injuries. The positive effect of predicted improvements in water and sanitation is probably one part of the explanation for a much lower percentage of DALYs related to diarrhea in the future.

A poll of more than 11, 300 readers of the *British Medical Journal* chose the introduction of clean water and sewerage – "the sanitary revolution" – as the most important medical milestone since 1840. Readers were given 10 days to vote on a shortlist of 15 milestones, and sanitation topped the poll, followed closely by the discovery of antibiotics and the development of anaesthesia. The work of the 19th century lawyer Edwin Chadwick, who pioneered the introduction of piped water and sewerage to people's homes, attracted 15.8% of the votes, while antibiotics took 15%, and anaesthesia took 14%.
(http://www.bmj.com/content/334/7585/111.2.extract)

DALYs attributable to risk factors

3.1 - 6



Water and sanitation causes a major part (9%) of GBD, that largely could be prevented. (WHO, 2008)

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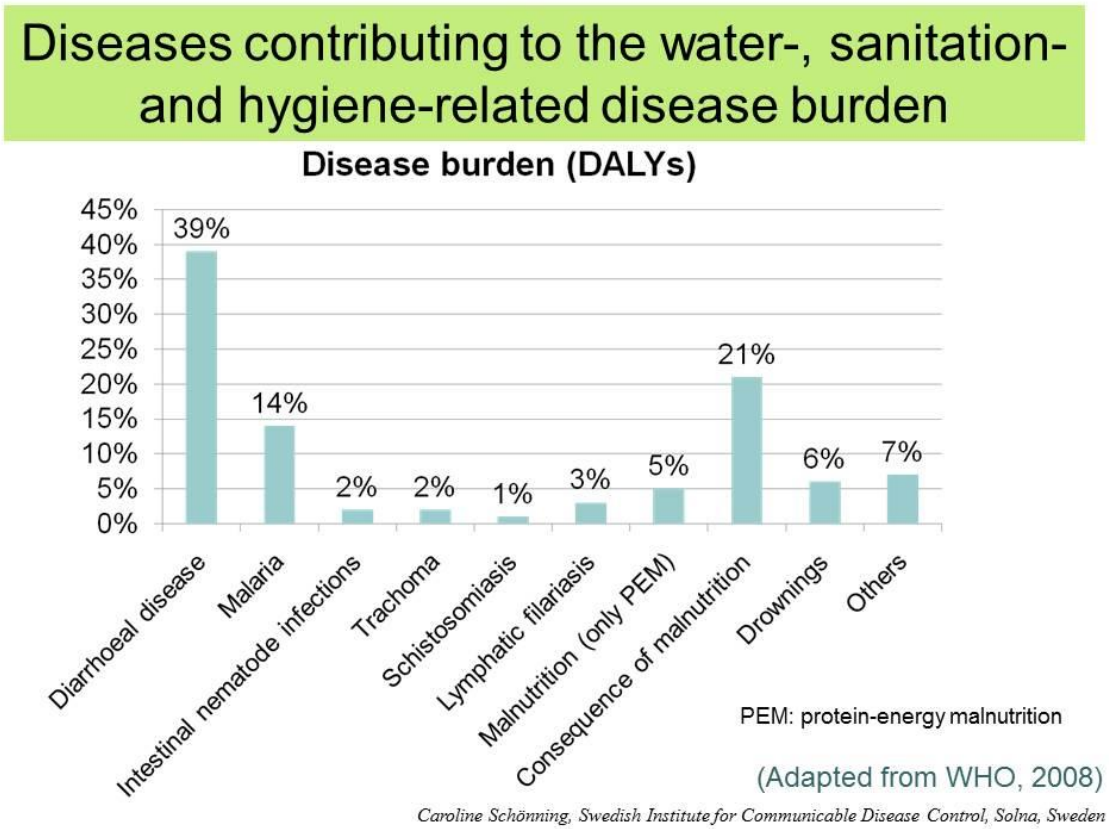
The above picture shows the 10 most important risk factors on a global scale. Malnutrition is by far the largest risk factor, resulting in almost 16% of the total global DALYs. Water and sanitation was in second place at the time the Global Burden of Disease report was published in 1996. It was responsible for 7% of the DALYs.

A more recent message regarding water and sanitation is that it causes a major part (9%) of GBD, and that it largely could be prevented. (WHO, 2008)
http://whqlibdoc.who.int/publications/2008/9789241596435_eng.pdf

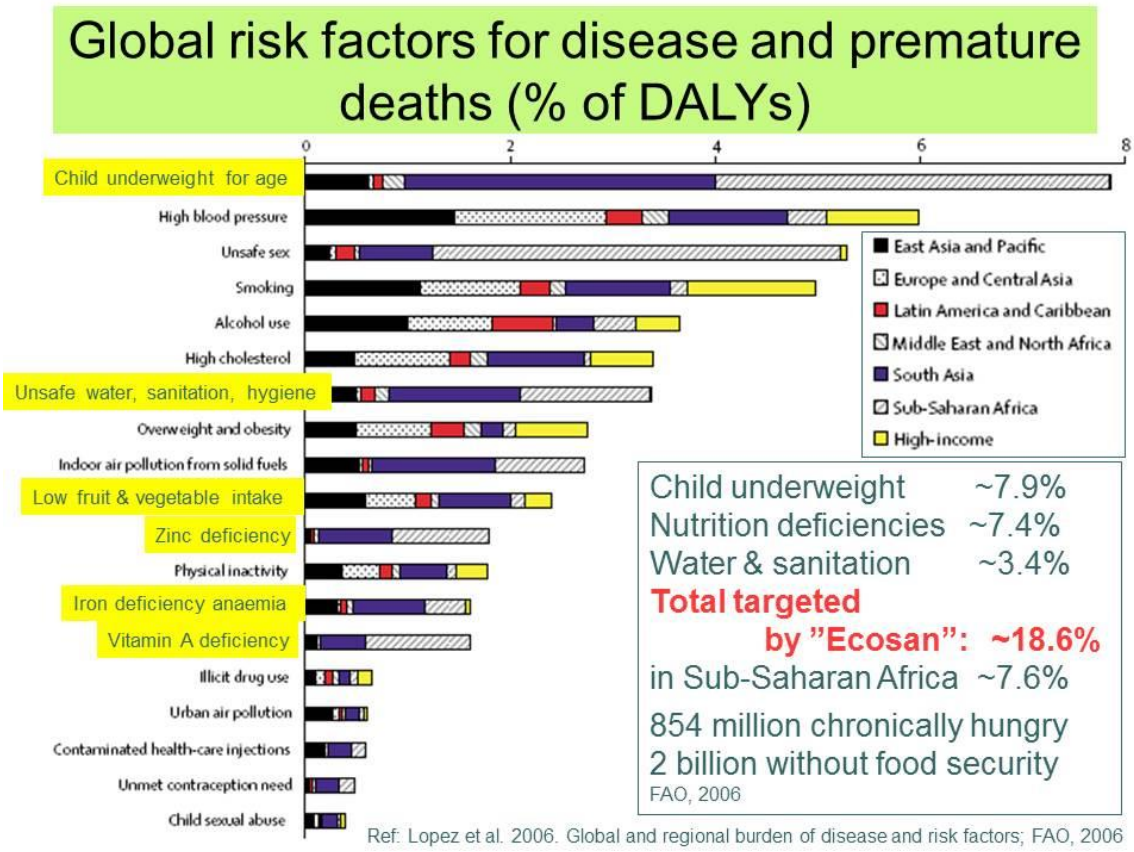
According to WHO, the world is on track to achieve the MDG target for access to safe drinking-water but more needs to be done to achieve the sanitation target. Fewer children are now dying and fewer are underweight, compared to 1990.

3.1 - 7



WHO try to address the health burden related to water, sanitation and hygiene including infectious diseases and malnutrition as well as drowning. As stated above, it is estimated that altogether 9% of this burden is caused by problems related to water supplies and sanitation and that most of these problems could be prevented by improvements related to drinking water, sanitation, hygiene and water resource management* (http://whqlibdoc.who.int/publications/2008/9789241596435_eng.pdf)

*The numbers will vary in this training material, due to differences in the literature cited. Estimates of the burden of disease related to various health problems, and related to various risk factors, are understandably difficult to calculate and estimate.



This graph is more detailed and shows the division of DALYs in the world. About 52% of the total burden of disease and premature deaths is specified in the diagram. The publication estimates that in 2006, 3.4% of the total worldwide DALY was related to water and sanitation. However, 7.9% was attributable to children being underweight and 7.4% to nutrition deficiencies. Theoretically most of this "ill-health" could be remedied with sanitation systems that protect water and the environment, and which contain and/or reuse the nutrients in excreta (e.g. "ecological sanitation").

About half of the burden due to underweight children is in Sub-Saharan Africa, and the main other part is in South Asia. The situation is similar for unsafe water, inadequate sanitation, zinc deficiency and vitamin A deficiency, while iron deficiency and low fruit and vegetable intake are more evenly distributed. Zinc is found in meat, poultry, , beans, nuts, whole grains and some seafood. Iron is found in liver and blood food, meats, seafood, fish, beans, peas, spinach and whole grains. Vitamin A is found in liver, beef, chicken, eggs, whole milk, fortified milk, carrots, mango, orange fruits, sweet potato, spinach, kale, and other green vegetables. Vitamin A is crucial for maternal and child survival and vitamin A deficiency also causes blindness.

Nutrients in excreta and the use of excreta for fertilizer are discussed in Module 4.8.

Further reading:

Lopez, A.D., Mathers, C.D., Ezzati, M., Jamison, D.T. and Murray, C.J.L. (2006) Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. Lancet (North American Edition) 367 (9524): 1747-1757.

FAO. 2006. The state of food insecurity in the world. Eradicating world hunger – taking stock 10 years after the world food summit. FAO. Rome, Italy.

Download: 2006 ftp://ftp.fao.org/docrep/fao/009/a0750e/a0750e00.pdf .

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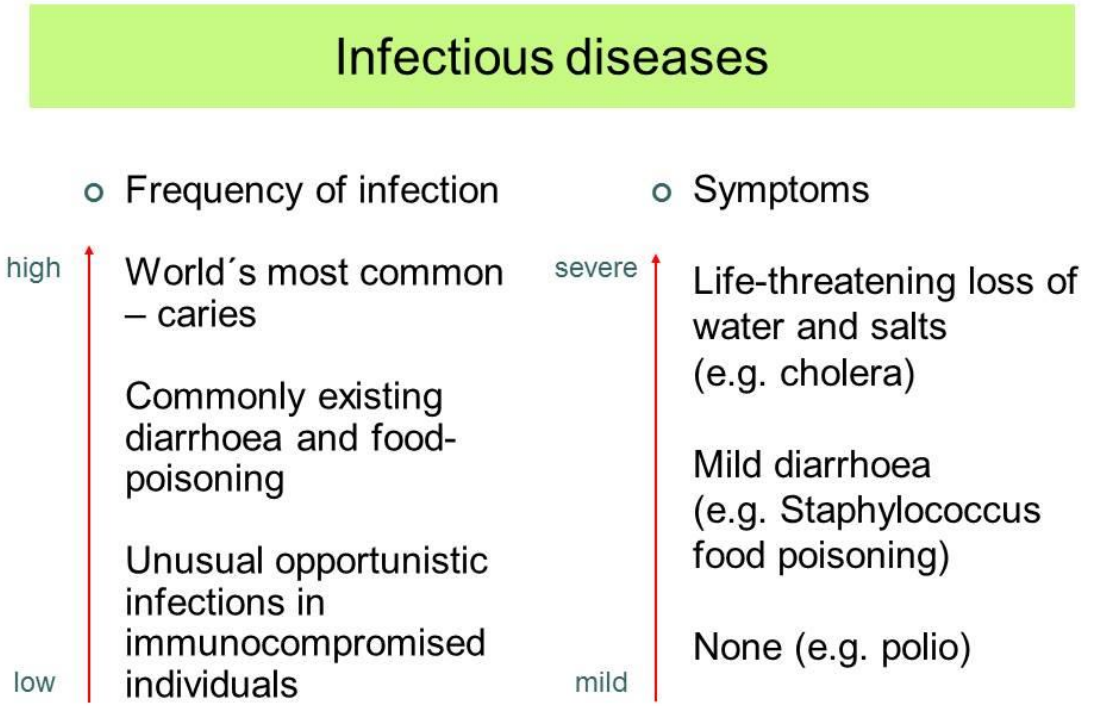
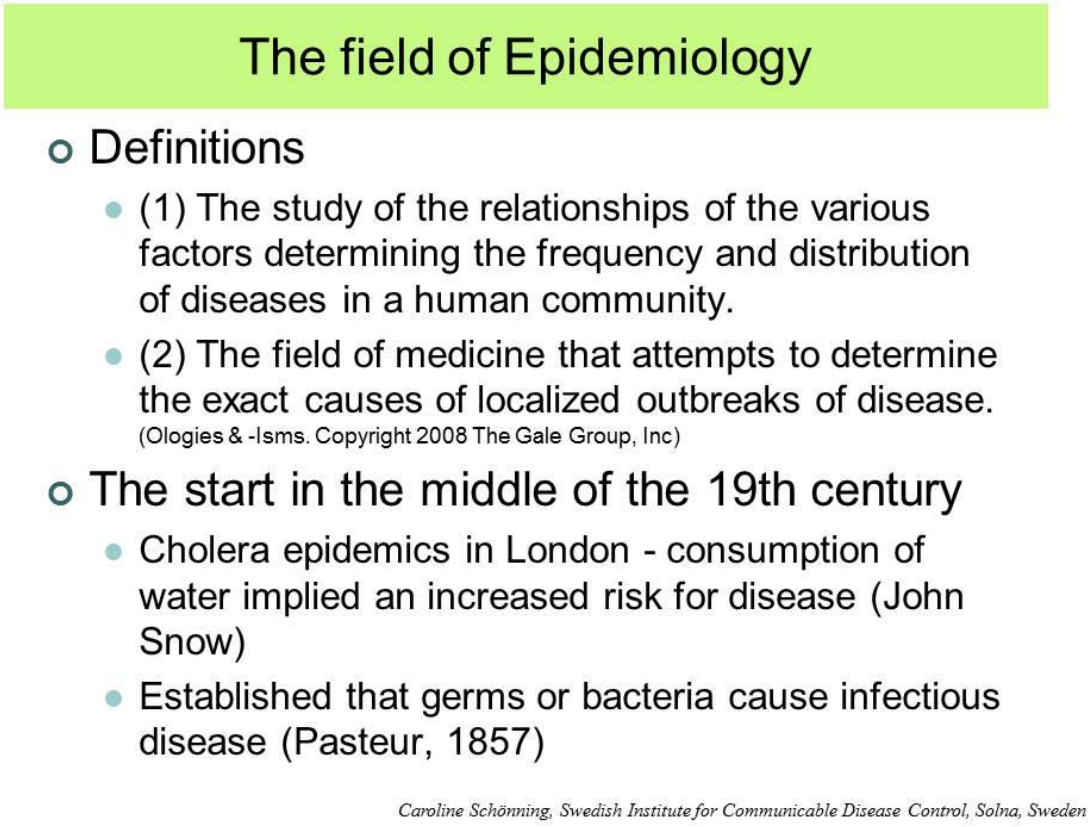


Infectious diseases are caused by microorganisms that invade the body and multiply. Normally, the body's natural defenses prevent microorganism from causing illness. Often, however, the microorganisms resist the body's defenses and cause infection. The severity of infections can range from mildly annoying, such as with a cold or diarrheal illness, to life threatening, as with meningitis or AIDS. The severity of the infection depends on the overall health of the patient and the virulence (strength) of the microorganism.

Infectious diseases are caused by different types of microorganisms: bacteria, viruses, parasitic protozoa, helminthes or fungi. The most common is caries (the highest frequency as presented in the above picture). Caries are caused by bacteria. The common cold is another example of a common and widespread infection, usually caused by viruses. Some diarrheal diseases are caused by common pathogens whereas others are rare. Infections vary in the symptoms they cause. There may be no symptoms at all as exemplified with polio above (also see slide 13). Some gastrointestinal infections may be asymptomatic in some individuals whereas others, like cholera, often result in watery diarrhea that may be life-threatening.

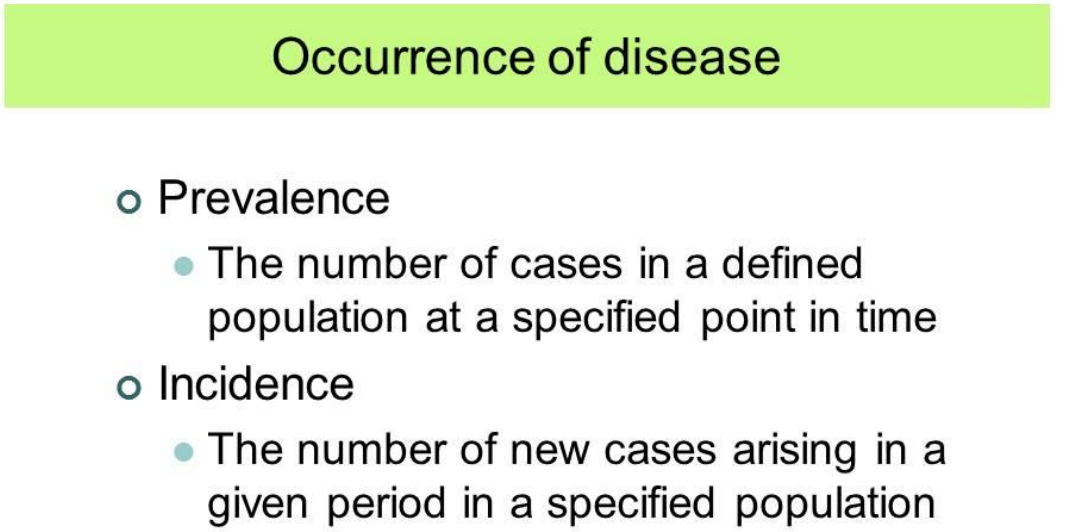


To further understand the modules in Chapter 3 and to be able to discuss the issues they deal with, basic information on epidemiology is needed. A short introduction with definitions is given to provide a common understanding of the terminology. For deeper studies of health issues, we refer to the *Further reading* section at the end of each module.

There are several common definitions for epidemiology. One of them is, in two parts (Ologies & -Isms. Copyright 2008 The Gale Group, Inc):

1. The study of the relationships of the various factors determining the frequency and distribution of diseases in a human community.
2. The field of medicine that attempts to determine the exact causes of localized outbreaks of disease.

Historically it can be said that epidemiology started during the cholera epidemics in London in the middle of the 19th century. John Snow recognized that the consumption of water from particular sources was associated with an increased risk of contracting the disease, although the disease-causing agent (*Vibrio cholerae*) had yet to be isolated and identified. In 1857 Pasteur established the theory that infectious disease is caused by germs or bacteria. The 19th century cholera epidemic in London is considered to be the first recorded outbreak of a waterborne disease. Other early recorded waterborne diseases included typhoid, dysentery and polio.

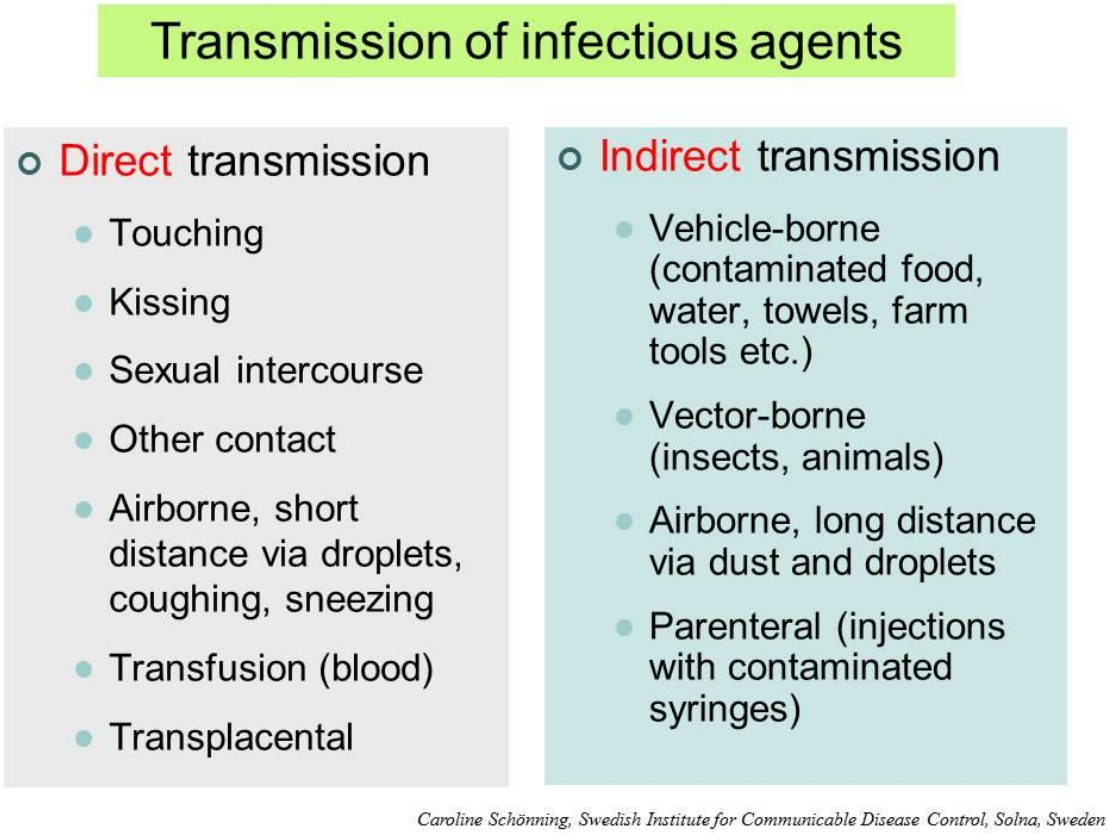


Epidemiological terms used to describe the health situation in a population include "prevalence" and "incidence".

Prevalence is the number of cases in a defined population at a specified point in time.

Incidence is the number of new cases arising in a given period in a specified population.

These measures are needed both for estimating health risks from water and sanitation systems and to be able to record improvements in the health status of a population after interventions (see Module 3.5).



Transmission of infectious diseases by pathogens (disease-causing microorganisms, infectious agents) occurs by direct transmission or by indirect transmission.

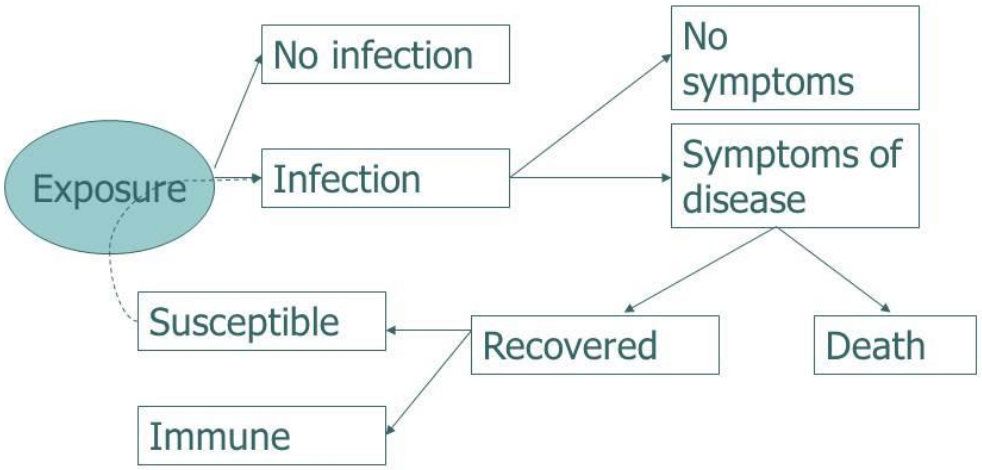
Direct transmission includes transmission from person to person by various types of contact, e.g. by touching and sexual intercourse, by exchange of blood during transfusions or from mother to child through the placenta. It also includes airborne transmission over short distances, such as coughing or sneezing.

Indirect transmission includes transmission via materials such as food and water that are ingested, but also possible exposure to pathogens by touching contaminated surfaces and then ingesting pathogens (i.e. hand-mouth). It also includes vector-borne transmission where animals in some way transport the pathogens, long distance airborne transmission e.g. by dust or droplets (aerosols) and finally parenteral transmission ("taken into the body or administered in a manner other than through the digestive canal") through injections with contaminated syringes.

When it comes to disease transmission related to water and sanitation it is thus indirect transmission we are dealing with. Exposure to pathogens and possible transmission of disease can occur when humans (and animals) come in contact with wastewater, faecal material, polluted or drinking water. How this exposure occurs is further described in Module 3.2.

Consequences of exposure

3.1 – 13



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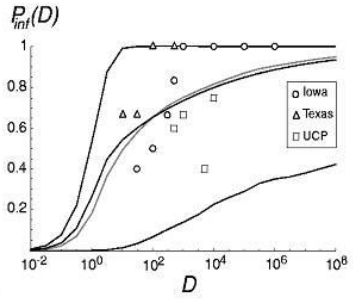
Exposure to pathogens does not necessarily lead to infection or disease. To become infected a certain number of pathogens needs to be ingested, corresponding to the infectious dose, which varies depending on pathogen/disease and also may vary from individual to individual. Even if an infection is established it does not necessarily involve symptoms. The individual having symptoms will either die or recover (perhaps with a residual disability). After recovering an individual is either susceptible or immune to the infection in question. How long the immunity lasts depend on the infection.

Symptoms can be mild or severe, and may vary during the course of the infection. Some infections have different stages, with for example initial symptoms (e.g. diarrhea) and long-lasting or chronic complications of another type (e.g. arthritis). Long-lasting symptoms which occur after the departure of the original disease are called sequela.

Infectious dose

3.1 - 14

- Minimum infectious dose
- ID_{50}
- Probability of infection
  - Dose-response curves
- Severity of disease depending on
  - Ingested dose
  - The condition of the mechanical barrier
  - The stability of the normal enteric flora
  - Immunity
  - The nutritional status of the individual



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The infectious dose was often reported as the minimum infectious dose – the lowest number of organisms known to result in infection, or as ID50, the dose at which 50% of exposed individuals will become infected. More recently, it has been possible to establish the probability of infection for some pathogens through so called dose–response curves that build on studies of healthy individuals who have ingested a specific number of the pathogens in question (see Module 3.4).

The severity of the disease and symptoms (i.e. the clinical manifestation of the infection) may depend on the ingested dose, the condition of the mechanical barrier, the stability of the normal enteric flora, the degree of immunity possessed by the individual and the nutritional status of the individual.

3.1 - 15

Immunity – vulnerable groups

Vulnerable groups in society:

- The old (elderly)
- Infants
- Pregnant women
- Immunocompromised
- Malnourished

http://www.oldpeoplearefunny.com/pictures/

These groups comprise about 20% of the general population and are growing

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Vulnerable groups are more sensitive to pathogens and thus a lower dose is required to cause an infection. These groups include the old, the very young, pregnant women and immunocompromised individuals such as HIV/AIDS patients and cancer patients. Together they comprise about 20% of the population and this percentage is increasing. There are however, large differences in the sizes of the groups in different parts of the world. When it comes to infectious diseases and risks from water and sanitation systems, one question is how to deal adequately with individuals in vulnerable groups. This is because when assessing risk and when estimating the demands on treatment systems, the starting point is often a health target or tolerable risk level, based on healthy individuals (see further Module 3.4). The actual level of vulnerability among children, for example, is seen during emergencies (e.g. flooding) when they are more exposed diarrheal disease and are very sensitive to dehydration.

The combination of malnutrition and infectious disease can be particularly pernicious. Protein-energy malnutrition (PEM) can impair the immune system, leaving malnourished children less able to battle common diseases such as measles, diarrhea, respiratory infections, tuberculosis, pertussis, and malaria. Vitamin A deficiencies are often worsened by infectious disease, and reciprocally, poor vitamin A status is likely to prolong or exacerbate the course of an illness such as measles. (Andrew Tomkins and Fiona Watson, *Malnutrition and Infection: A Review* (United Nations Administrative Committee on Coordination/Subcommittee on Nutrition, WHO, Geneva, 1989, pp. 5–6).

Epidemiology - Definitions

3.1 - 16

Pandemic: An epidemic (a sudden outbreak) that becomes very widespread and affects a whole region, a continent, or the world.

By contrast:
An **epidemic** affects more than the expected number of cases of disease occurring in a community or region during a given period of time.

An **endemic** is present in a community at all times but in low frequency.

(http://www.medterms.com/script/main/art.asp?articlekey=4751)

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Epidemic: An epidemic affects more than the expected number of cases of disease occurring in a community or region during a given period of time. A sudden severe outbreak within a region or a group as, for example, AIDS in Africa or AIDS in intravenous drug users.

Pandemic: An epidemic (a sudden outbreak) that becomes very widespread and affects a whole region, a continent, or the world.

Endemic: An endemic is present in a community at all times but in low frequency. An endemic is continuous as in the case of malaria in some areas of the world or as with illicit drugs in some neighborhoods.

The word "pandemic" comes from the Greek **pan** ("all") + **demos** ("people or population") = **pandemos** ("all the people"). A pandemic affects all (nearly all) of the people. By contrast, **epi-** means "upon." An epidemic is visited upon the people. **En-** means "in." An endemic is in the people. (http://www.medterms.com/script/main/art.asp?articlekey=4751)

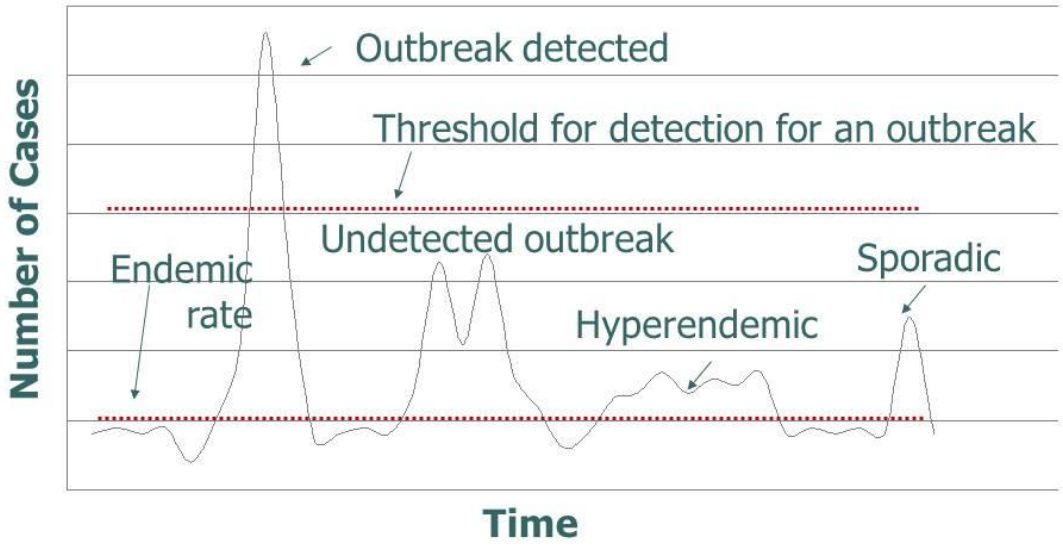
However, in 2009 during the "flu pandemic" the definition of pandemic (according to the WHO) was debated and also changed. Originally three conditions had to be met before a disease to be declared a pandemic:

- The disease had to be new to a population, or had not surfaced for a long time
- This disease had to be caused by agents that infected humans, causing serious illness; and
- The agents had to be capable of spreading easily and sustainably among humans.

The original definition also contained two other conditions – there had to be a high morbidity and a high mortality rate. In other words, a lot of people had to fall seriously ill, and a lot of them had to die. This did not happen with the H1N1 flu. Although many people caught the illness, most experienced only mild symptoms. Only a small percentage became seriously ill, and a smaller percentage died. At the time of the pandemic declaration, nearly 30,000 people in 74 countries had been infected but only 144 people died. The death rate was less than 0.5 percent, which is very low. In contrast, SARS (severe acute respiratory syndrome) had a death rate of about 15 percent but SARS was not declared a pandemic because few people got infected.

Epidemic to endemic illnesses as detected by health surveillance

3.1 - 17



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At any given time some infections are always occurring. This is the so-called endemic background level (the endemic rate). This level varies depending on country and region. To detect disease outbreaks, the number of cases needs to exceed a certain number. Sporadic cases (at rates higher than the endemic level) and smaller outbreak situations may be difficult to detect.

Health surveillance is the obligatory or voluntary reporting of diseases in a society. For an infectious disease to be reported several steps need to be taken:

1) The infected person must seek medical help
2) The doctor needs to arrange for a clinical sample to be taken
3) The correct analysis must be ordered from the laboratory
4) The laboratory must identify the disease-causing organism
5) The clinical result must be reported to the health surveillance system.

The efficiency of health surveillance systems varies greatly between societies. It is however well recognized that surveillance systems always underestimate the actual number of cases. Targeted epidemiological investigations can be a complement to general surveillance for determining the prevalence of a disease in a society. Such investigations are often expensive and cumbersome to conduct since clinical samples must be collected from a large number of persons.

3.1 - 18

Diarrhoea and sanitation

- Causes ~1/5 of deaths in children <5 years (1.5 million)
- Has decreased, in 1980´s estimated 2/3 of deaths
- Less significant decrease in diarrhoeal disease in low-income countries
- Infections related to water and sanitation
- 4.1% of the total DALY
- 88% of the burden attributable to unsafe water supply, sanitation and hygiene
- Improved sanitation can reduce diarrhoea by ~32%
- 391 million cases averted if MDG target met

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

Diarrhea causes approximately 1/5 of deaths in children under 5 years of age (about 1.5 million deaths per year). The impact of diarrhea has decreased since the 1980s when it was estimated to account for 2/3 of deaths. However there has not been a significant decrease in diarrheal disease in low-income countries. In 2004 diarrheal disease accounted for an estimated 4.1% of the total DALY global burden of disease and is responsible for the deaths of 1.8 million people every year (WHO, 2004). It was estimated that in 2004 88% of that burden was attributable to unsafe water supply, sanitation and hygiene and mostly affects children in developing countries.

A significant amount of disease could be prevented especially in developing countries through better access to safe water supplies, adequate sanitation facilities and better hygiene practices.

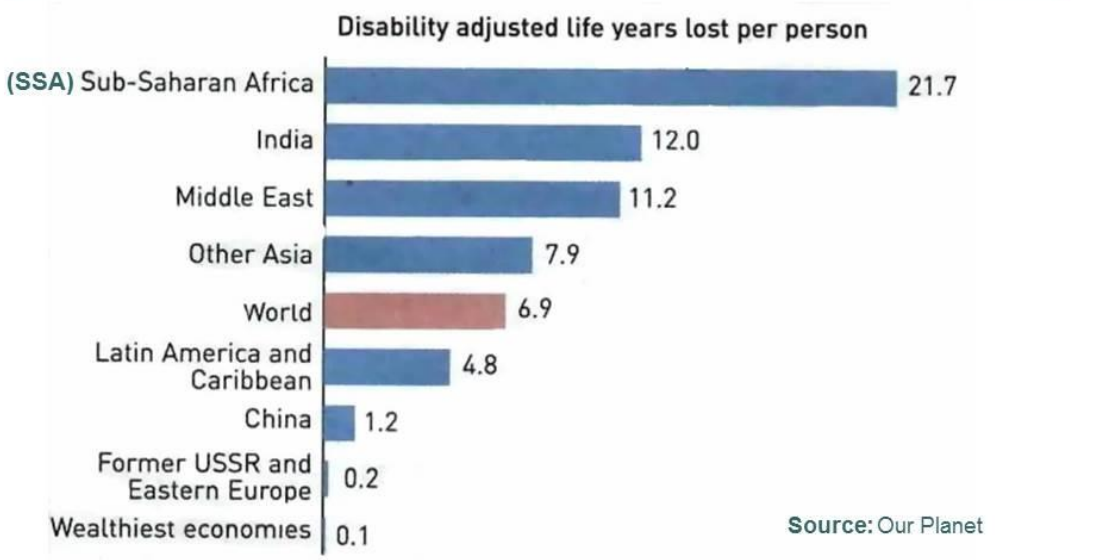
Improved sanitation has been calculated to reduce diarrhea by 32%. IF the sanitation part of the MDG target to "reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation" by 2015 is met, 391 million cases of diarrhea will be averted each year.

http://www.who.int/water_sanitation_health/diseases/burden/en/index.html

http://www.who.int/water_sanitation_health/hygiene/securingsanitation1.pdf

Regional differences in average health burdens from diarrhoeal diseases

3.1 - 19



Current annual diarrhea cases in SSA:
1.2 billion which lead to 769,000 dead children, mostly under 5 years

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

This is the number of DALYs per person that are lost due to diarrhea in different parts of the world. The situation is worst in Sub-Saharan Africa where there are 1.2 billion annual cases, resulting in around 800,000 children losing their lives.

Diarrhoeal diseases – Outbreaks related to water and sanitation

3.1 - 20

- Cholera
  - 36 reported outbreaks from 2006-2009 (WHO)
  - Risk during flooding
  - "Natural environmental" spread
- Typhoid fever
  - Also endemic
- Shigellosis

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

Outbreaks may occur when major failures in water or sanitation systems occur. The definition of an outbreak is that a larger number of persons (in theory however two is enough) gets infected by the same type of pathogen from the same source, approximately at the same time. However, the incubation time (the time from exposure to the onset of disease) may vary substantially. Outbreaks may also include secondary cases caused by person-to-person transmission.

Globally, cholera is one of the more severe diarrheal diseases that often occur in outbreak-type situations. Cholera is caused by a waterborne pathogen that infects 3 to 5 million people annually and leads to an estimated 120,000 deaths each year. It is considered to be one of the largest problems during major floods. The WHO reported 36 outbreaks from 2006 to 2009.

In 2010 Dr Rita Colwell received the Stockholm Water Prize for her findings that the causative agent for cholera, *Vibrio cholera*, could survive by attaching to zooplankton. This led to her groundbreaking discovery that certain bacteria, including the *Vibrio* species, can enter a dormant stage that is able to revert to an infectious state under the proper conditions. This means that even when there are no disease outbreaks, rivers, lakes and oceans can serve as reservoirs for these bacteria. These findings refuted the conventional assumption that cholera was only spread from person to person, food or drinking water and that its presence in the environment could only be due to the release of sewage. As a result of her work, scientists are now able to link changes in the natural environment to the spread of the disease.

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

Typhoid fever is a bacterial disease, caused by *Salmonella typhi* (see below) that is endemic in several parts of the world with an estimated 16 million cases per year. It is transmitted through the ingestion of food or drink contaminated by the faeces or urine of infected people. It also occurs in outbreak situations, for example in the Democratic Republic of the Congo from September 2004 to January 2005 there were 42,564 cases and 214 deaths. Very poor sanitary conditions and a lack of drinking water have been reported in areas where there have been typhoid fever outbreaks.

Shigella is a genus of bacteria that are a major cause of diarrhea and dysentery (diarrhea with blood and mucus in the stools) throughout the world. The bacteria are transmitted by the ingestion of contaminated food or water, or through person-to-person contact. All outbreaks reported by the WHO during the 21st century have been in Africa.

For example in Lesotho there was an outbreak in which there were 1,862 cases with 28 deaths (from November 1999 to January 2000). Adults were more affected than children. Problems identified were a "*lack of protection of latrines and inadequate water supplies*". All unprotected water springs/wells which were inspected were contaminated while most of the protected springs had good quality water.

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3.1 - 21

Cholera epidemic

- Acute watery diarrhoea, very deadly without rapid treatment
- Affects adults as much as children, especially informal caretakers
- High political profile : can be used as a political leverage

- Characteristics for cholera outbreaks
  - high attack rate
  - low mortality
  - economic and social burden
- Factors of spread
  - density of population
  - transportation facilities
  - living conditions
  - environmental reservoirs

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

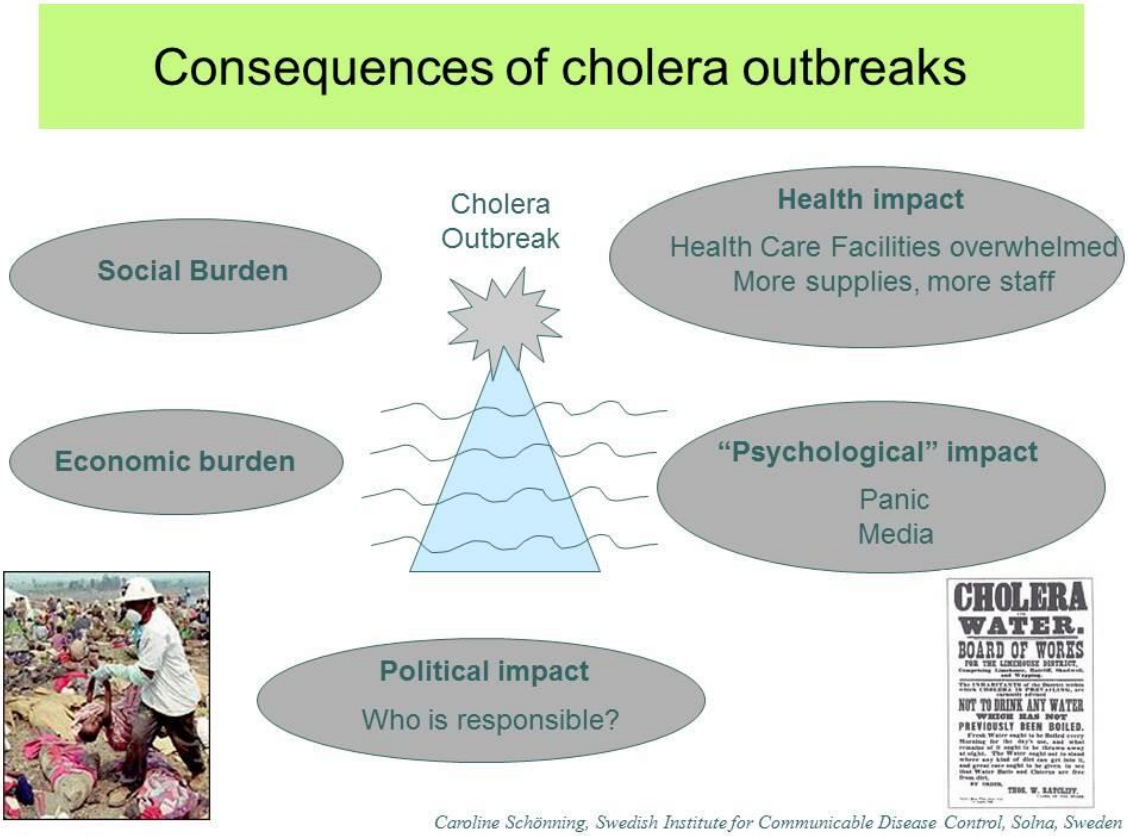
Cholera outbreaks can occur sporadically in any part of the world where water supplies, sanitation, food safety and hygiene practices are inadequate. Overcrowded communities with poor sanitation and unsafe drinking-water supplies are most frequently affected.

Cholera is an acute infection of the intestine which begins suddenly with painless watery diarrhea, nausea and vomiting. Most people who become infected have very mild diarrhea or are symptom-free but some groups of the population, particularly malnourished people, experience more severe symptoms. Severe cholera cases present with profuse diarrhea and vomiting. Severe, untreated cholera can lead to rapid dehydration and death. If untreated, 50% of people with severe cholera will die, but prompt and adequate treatment reduces this to less than 1% of cases.

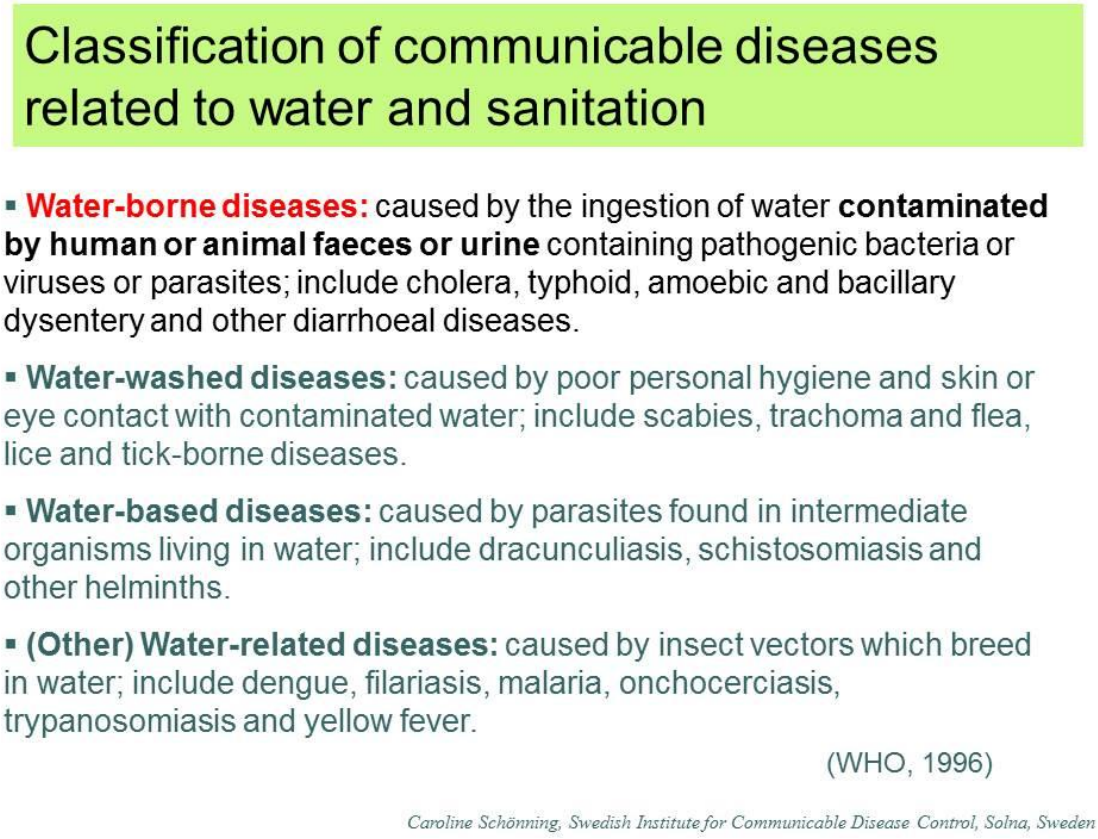
In the year 2000 cholera cases and deaths officially reported to the WHO came from 27 countries in Africa, 9 countries in Latin America, 13 countries in Asia, 2 countries in Europe, and 4 countries in Oceania. Control of cholera is a major problem in several Asian countries as well as in Africa. In the year 2000, some 140,000 cases resulting in approximately 5,000 deaths were officially notified to the WHO. Africa accounted for 87% of these cases. After almost a century of no reported cases of the disease in Latin America, cholera reappeared in 1991. However, the number of cases reported in Latin America has been steadily declining since 1995.

http://www.who.int/water_sanitation_health/diseases/cholera/en/

3.1 - 22



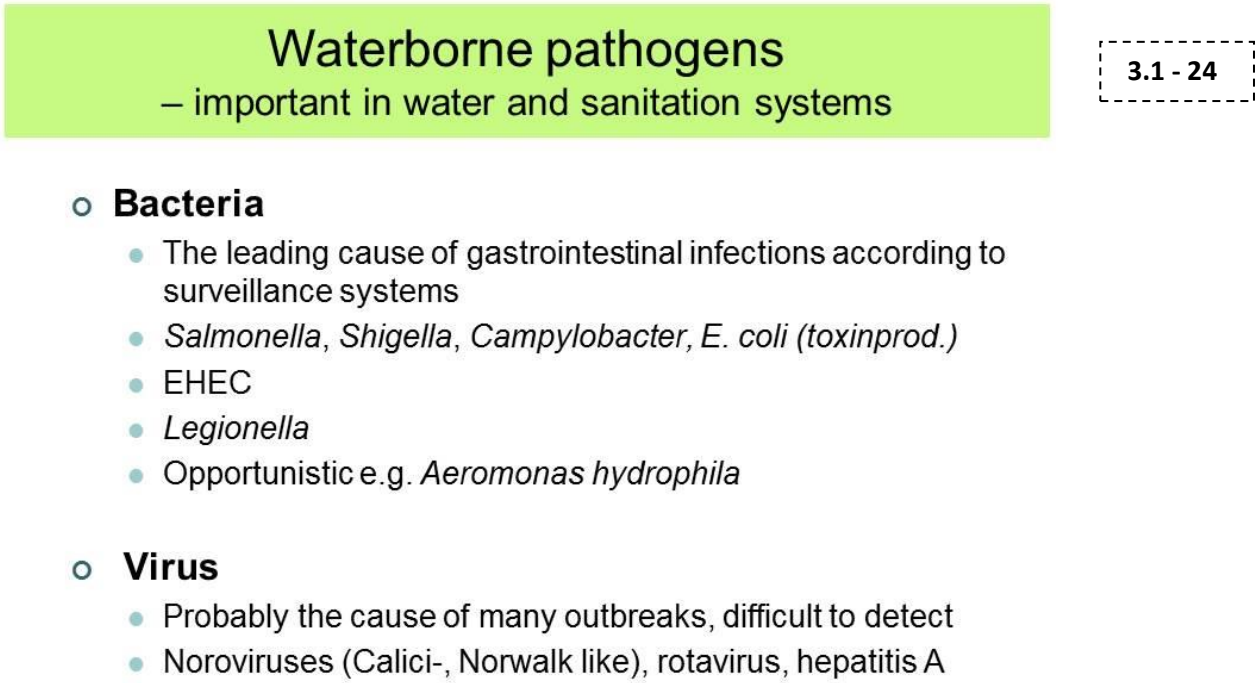
The consequences of outbreaks, and especially of cholera due to the high mortality, are multi-faceted.



Another term for infectious diseases is "communicable diseases". They can also be called contagious diseases. To classify the types of transmission of diseases via water the following division can be made:

- **Water-borne diseases:** caused by the ingestion of pathogenic bacteria, viruses or parasites contained in water contaminated by human or animal faeces or urine. They include cholera, typhoid, amoebic and bacillary dysentery and other diarrheal diseases.
- **Water-washed diseases:** caused by poor personal hygiene and skin or eye contact with contaminated water. They include scabies, trachoma and flea, lice and tick-borne diseases.
- **Water-based diseases:** caused by parasites found in intermediate organisms living in water. They include dracunculiasis, schistosomiasis and other helminths.
- **(Other) Water-related diseases:** caused by insect vectors which breed in water. They include dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever.

In the following material we deal mainly with the first group – waterborne diseases, since they by definition are directly linked to excreta and sanitation. The other groups may also be of concern when it comes to sanitation systems. Waterborne diseases are of concern in all settings, whereas many of the other diseases mainly are confined to tropical areas. More recently the term **water-related diseases** have been used to cover all these groups.



Pathogens can be bacteria, viruses, protozoa or helminths. Fungi may also infect humans but are not commonly considered of importance in water and sanitation systems.

Common bacterial causes of gastrointestinal infections are *Salmonella*, *Shigella*, *Campylobacter* and toxin-producing *E. coli (Escherichia coli)*. These can thus be present in wastewater and may contaminate other water (see Module 3.2). EHEC (enterohaemorrhagic *E. Coli)* is one type of *E. coli* that causes severe disease. Waterborne outbreaks have been detected. A Swedish outbreak from food but caused by water is described in Module 3.2. *Legionella* is transmitted through aerosols, from e.g. showers, not by drinking water. There are also so-called opportunistic pathogens that generally are harmless but may cause disease in immuno-compromised individuals.

Viruses are more difficult to detect than bacteria but are probably a cause of many waterborne outbreaks where the causative agent (microorganism) is not found. In the Western/developed world viruses are assumed to cause the majority of gastrointestinal infections, for example norovirus is common. Hepatitis A is a common waterborne and foodborne virus and rotavirus is common around the world, causing many deaths among children in developing countries. Viruses generally have lower infectious doses than bacteria.

Some of these bacteria and viruses are described in more detail below.

Waterborne pathogens (con´t) – important in water and sanitation systems

3.1 - 25

- **Protozoa**
  - Complicated life cycles with resistant stages (chlorine)
  - *Giardia*, *Cryptosporidium, Entamoeba*
  - Low infectious dose
  - In Milwaukee (USA) in 1993, 400,000 were infected by *Cryptosporidium*
- **Helminths (worms)**
  - Varying transmission routes, e.g. soilborne
  - *Ascaris, Trichuris, Schistosoma* (bilharzia), hookworm
  - A large problem in many developing countries

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

Parasitic protozoa have complex life cycles that often include a stage that is very resistant to various environmental pressures/factors and chlorine. *Giardia*, *Cryptosporidium* and *Entamoeba* are known to have caused waterborne disease outbreaks. The largest reported outbreak was caused by *Cryptosporidium* in Milwaukee 1993. An estimated 400,000 people were infected by insufficiently treated drinking water.

Helminths are mainly a problem in developing regions. They have varying transmission routes, for example the eggs that are excreted in faeces from an infected person may require a latency period in soil before becoming infectious. Common helminths include *Ascaris, Trichuris, Schistosoma* (bilharzia), and hookworm.

Protozoa and helminths generally have low infectious doses.

Some important diseases are presented in more detail below.

3.1 - 26

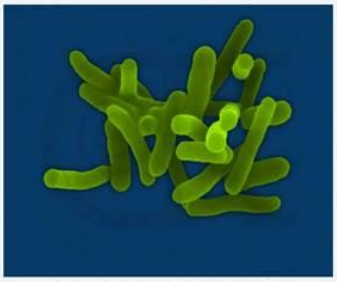
Shigella

4 Serogroups/ 4-5 Species:

A	*S. dysenteriae*
B	*S. flexneri*
C	*S. boydii*
	S. paradysenteriae
D	*S. sonnei*

Many different Serovars

(i) *Shigella*



Shigella sonnei - rod prokaryote; causes shigellosis (bacterial dysentery)

All cause bacillary dysentery or shigellosis.

Shigellosis is bloody feces associated with intestinal pain.

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

Shigellosis is an infectious disease caused by a group of bacteria called *Shigella*. Most that are infected with *Shigella* develop diarrhea, fever, and stomach cramps starting a day or two after they are exposed to the bacteria. The diarrhea is often bloody. Shigellosis usually resolves in 5 to 7 days. Persons with shigellosis in developed countries rarely require hospitalization. A severe infection with high fever may be associated with seizures in children under two years old. Some persons who are infected may have no symptoms at all, but may still pass the *Shigella* bacteria to others.

In the developing world, *Shigella flexneri* predominates. Epidemics of *S. dysenteriae* type 1 have occurred in Africa and Central America with fatality rates of 5–15%.

A small inoculum (10 to 200 organisms) is sufficient to cause infection. As a result, spread can easily occur by the fecal-oral route and occurs in areas where hygiene is poor. Epidemics may be foodborne or waterborne. *Shigella* can also be transmitted by flies and sexual contact.

(http://www.cdc.gov/nczved/divisions/dfbmd/diseases/shigellosis/technical.html)

3.1 - 27

Salmonella infection – Salmonellosis and Typhoid fever

Salmonellosis – diarrhea, fever, and abdominal cramps

- Caused by a variety of serotypes, e.g. *Salmonella* Typhimurium and *Salmonella* Enteridis
- Foods contaminated with animal faeces
  - Animal origin (meat, poultry, eggs), vegetables
  - Pets – handwashing important

Paratyphoid and Typhoid fever - fever and other symptoms

- Life threatening
- Caused by *Salmonella* Typhi
- Transmitted by contaminated food or water
- More common in areas with low sanitary standards

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

There are many different kinds of *Salmonella* bacteria. The *Salmonella* serotype Typhimurium and *Salmonella* serotype Enteridis are the most common in the United States. Most persons infected with *Salmonella* develop diarrhea, fever, and abdominal cramps 12 to 72 hours after infection. The illness usually lasts four to seven days, and most persons recover without treatment. However, in some persons, the diarrhea may be so severe that the patient needs to be hospitalized. In these patients, the *Salmonella* infection may spread from the intestines to the blood stream, and then to other body sites and can cause death unless the person is treated promptly with antibiotics. The elderly, infants, and those with impaired immune systems are more likely to have a severe illness. *Salmonella* live in the intestinal tracts of humans and other animals, including birds. *Salmonella* are usually transmitted to humans by eating foods contaminated with animal feces. Contaminated foods usually look and smell normal. Contaminated foods are often of animal origin, such as beef, poultry, milk, or eggs, but any food, including vegetables, may become contaminated. Thorough cooking kills *Salmonella*. Food may also become contaminated by the hands of an infected food handler who did not wash hands with soap after using the bathroom.

Salmonella may also be found in the faeces of some pets, especially those with diarrhea, and people can become infected if they do not wash their hands after contact with pets or pet feces.

(http://www.cdc.gov/nczved/divisions/dfbmd/diseases/salmonellosis/technical.html)

Paratyphoid and typhoid fever are life-threatening illnesses caused by *Salmonella* Paratyphi and *Salmonella* Typhi, respectively. In the United States about 400 cases occur each year, and 75% of these are acquired while travelling internationally. Typhoid fever is still common in the developing world, where it affects about 21.5 million persons each year. *Salmonella* Typhi lives only in humans. Persons with typhoid fever carry the bacteria in their bloodstream and intestinal tract. In addition, a small number of persons, called carriers, recover from typhoid fever but continue to carry the bacteria. These people can be a source of infection for others.

You can get typhoid fever if you eat food or drink beverages that have been handled by a person who is shedding *S. Typhi* or if sewage contaminated with *S. Typhi* bacteria gets into the water you use for drinking or washing food. Therefore, typhoid fever is more common in areas of the world where hand washing is less frequent and where water is likely to be contaminated with sewage.

Once *S. Typhi* bacteria are eaten or drunk, they multiply and spread into the bloodstream. The body reacts with fever and other signs and symptoms.
(http://www.cdc.gov/nczved/divisions/dfbmd/diseases/typhoid_fever/)

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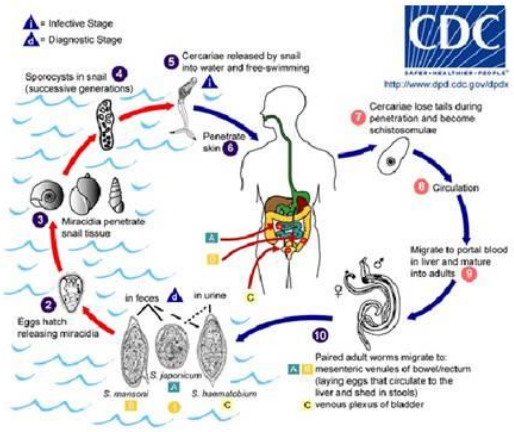
3.1 - 28

Schistosoma



- Also known as bilharzia
- 200 million people are infected worldwide
- Variety of symptoms
- Freshwater contaminated by urine or faeces
- Life-cycle requires specific snail as host

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

Schistosomiaisis, also known as bilharzia, is a disease caused by parasitic worms. You become infected when your skin comes in contact with contaminated freshwater in which certain types of snails that carry schistosomes are living. More than 200 million people are infected worldwide each year.

Schistosomiaisis in humans is caused mainly by infection with *Schistosoma mansoni*, *S. haematobium*, or *S. japonicum*. Within days of becoming infected, individuals may develop a rash or itchy skin. Fever, chills, coughs, and muscle aches can begin within 1–2 months of infection.

Fresh water becomes contaminated by *Schistosoma* eggs when infected people urinate or defecate in the water. The eggs hatch, and if certain types of snails are present in the water, the parasites grow and develop inside the snails. The parasite leaves the snail and enters the water where it can survive for about 48 hours. *Schistosoma* parasites can penetrate the skin of persons who are wading, swimming, bathing, or washing in contaminated water. Within several weeks, worms grow inside the blood vessels of the body and produce eggs. Some of these eggs travel to the bladder or intestines and are passed into the urine or stool.

Eggs travel to the liver or pass into the intestine or bladder, causing inflammation or scarring. Children who are repeatedly infected can develop anaemia, malnutrition, and learning difficulties. After years of infection, the parasite can also damage the liver, intestines, lungs, and bladder. Rarely, eggs are found in the brain or spinal cord and can cause seizures, paralysis, or spinal cord inflammation.

Symptoms of schistosomiasis are caused by the body's reaction to the eggs produced by worms, not by the worms themselves. The reaction to the eggs in tissues causes inflammation and disease.

http://www.cdc.gov/ncidod/dpd/parasites/schistosomiasis/factsht_schistosomiasis.htm

Schistosomiasis is endemic in 76 countries, most of which are in Africa. Schistosomiasis is a water-based disease which is considered the second-most important parasitic infection after malaria in terms of public health and economic impact.

In Asia, cattle and water buffalo can be important reservoirs of hosts eggs. Those who work in irrigation or fishing are at increased risk of contracting schistosomiasis. With the increase in wilderness or "off-track" tourism, more tourists are becoming infected.

At least 600 million people are at risk of infection and 200 million are infected with schistosomiasis. Of these 20 million are severely affected and 120 million have symptoms. An estimated 80% of transmission takes place in sub-Saharan Africa.
http://www.who.int/water_sanitation_health/diseases/schisto/en/

The life cycle of *Schistosoma haematobium*

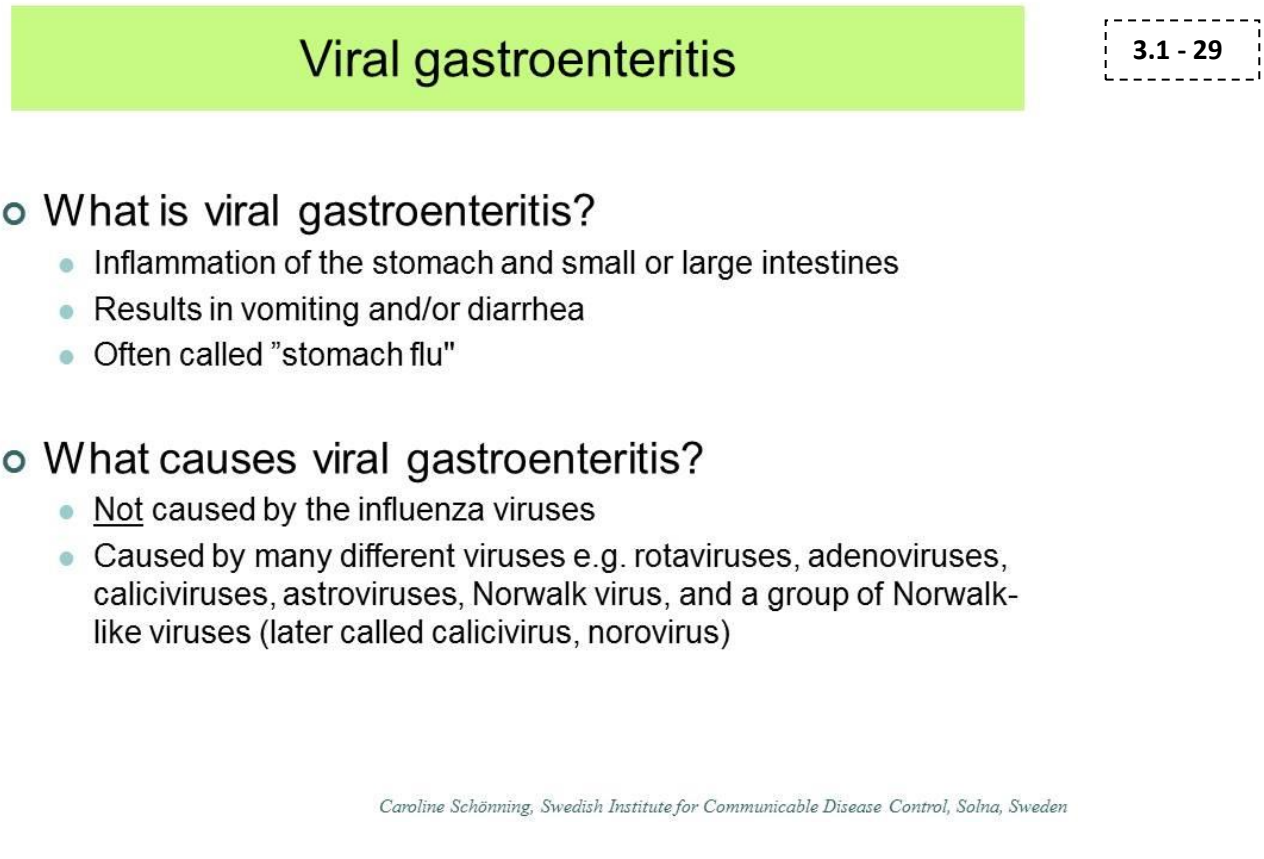
Schistosoma haematobium has a complex life cycle, which takes place in humans, and in a freshwater snail which acts as an intermediate host. *Schistosoma* needs the right conditions to complete its life cycle, including both hosts (humans and snails) and fresh water. Humans become infected when they come into contact with the infective stage of the life cycle (the cercaria) in water, where the snail hosts are found.

Eggs are passed out with the urine. If this is into water (e.g. a pond or lake) the eggs will hatch into miracidia. The miracidia then enter a fresh water snail (*Bulinis sp.*). In the snail the larvae go through further stages of development and multiplication.

The next stage of the schistosome development is cercaria, which are released from the snail. If these come into contact with humans, e.g. when they are swimming, bathing or wading in the water, the cercariae can enter unbroken skin – often on the feet or ankles (shedding their tail as they do so). Once inside a person, the larvae migrate through the blood system to the liver. In the veins of the liver, the schistosomes undergo further development and mature into adults.

The adults leave the blood system of the liver to migrate again, finally ending up in blood vessels around the urinary bladder (and less often, other organs). Here, eggs are released against the bladder wall. These eggs then penetrate into the inside of the bladder, where they are passed out with the urine – to begin the cycle again.

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



Viral gastroenteritis is an inflammation of the stomach and small or large intestines. It is an infection caused by a variety of viruses and results in vomiting or diarrhea. It is often called the "stomach flu," but is not caused by the influenza viruses. Many different viruses can cause gastroenteritis, including rotaviruses, adenoviruses, caliciviruses, astroviruses, Norwalk virus, and a group of Norwalk-like viruses. The infectious doses for these viruses are generally low.

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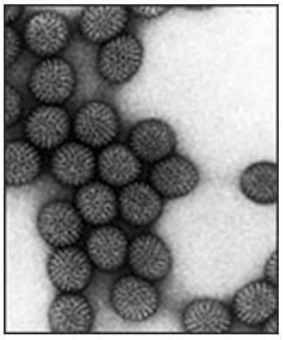
Rotavirus

3.1 - 30

- Rotavirus is the most common cause of severe diarrhea among children
- Globally, rotavirus is estimated to cause 527,000 deaths in children annually
- Vomiting and watery diarrhea for 3 - 8 days, and fever and abdominal pain occur frequently
- Immunity after infection is incomplete
- Vaccination possible but not widespread



(http://www.cdc.gov/rotavirus)

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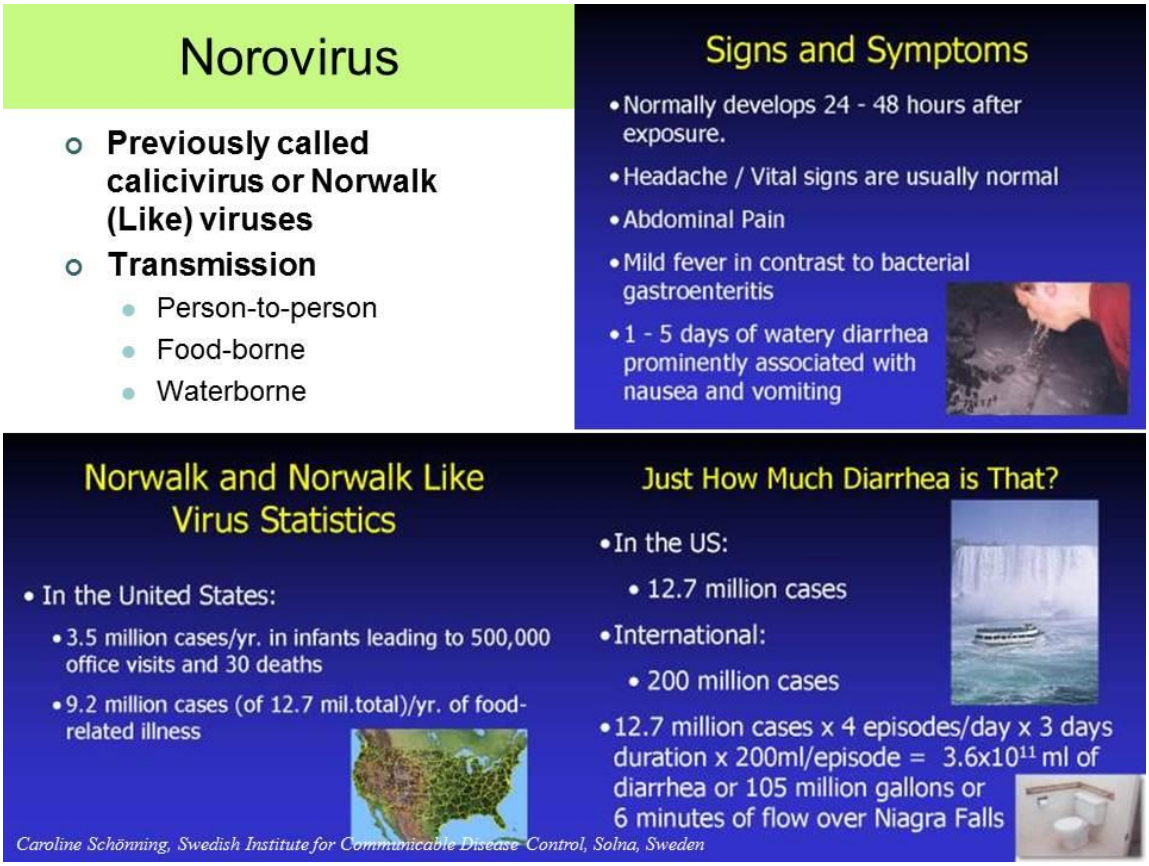
Rotavirus is the most common cause of severe diarrhea among children. Prior the introduction of rotavirus vaccines in the United States in 2006, rotavirus resulted in the hospitalization of approximately 55,000 US children each year. Globally, rotavirus is estimated to cause 527,000 deaths in children annually. The incubation period for rotavirus disease is approximately two days. The disease is characterized by vomiting and watery diarrhea for 3–8 days, and fever and abdominal pain occur frequently. Immunity after infection is incomplete, but repeat infections tend to be less severe than the original infection. (http://www.cdc.gov/rotavirus/)



Noroviruses (genus *Norovirus*, family *Caliciviridae*) are a group of related, single-stranded RNA, non-enveloped viruses that cause acute gastroenteritis in humans. Norovirus is the official genus name for the group of viruses previously described as "Norwalk-like viruses" (NLV). http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus.htm

The symptoms of norovirus illness usually include nausea, vomiting, diarrhea, and some stomach cramping. Sometimes people also have a low-grade fever, chills, headaches, muscle aches, and a general sense of tiredness. The illness often begins suddenly, and the infected person may feel very sick. In most people the illness is self-limiting, with symptoms lasting for about 1 or 2 days. In general, diarrhea is more common in children and vomiting is more common in adults. Noroviruses are found in the stool and vomit of infected people. People can become infected with the virus in several ways:

- by eating food or drinking liquids that are contaminated with norovirus,
- by touching surfaces or objects contaminated with norovirus, and then placing their hand in their mouth, and
- by having direct contact with another person who is infected (for example, when caring for someone with illness, or sharing foods or eating utensils with someone who is ill).

http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus-qa.htm

In the United States, the CDC (Centers for Disease Control and Prevention) estimates that more than 21 million cases of acute gastroenteritis each year are due to norovirus infections, and more than 50% of all foodborne disease outbreaks can be attributed to noroviruses.

Among the 232 outbreaks of norovirus illness reported to CDC from July 1997 to June 2000, 57% were foodborne, 16% were due to person-to-person contact, 3% were waterborne, and in 23% of outbreaks, the cause of transmission was not determined. The infection is a major cause of diarrhea in the developed world but has been less discussed in relation to sanitation in developing countries.

Most foodborne outbreaks of norovirus illness are likely to arise though direct contamination of food by a food handler immediately before its consumption. Outbreaks have frequently been associated with consumption of cold foods, including various salads, sandwiches, and bakery products. Liquid items (e.g. salad dressing or cake icing) that allow the virus to mix evenly are often implicated as a cause of outbreaks. Food can also be contaminated at its source, and oysters from contaminated waters have been associated with widespread outbreaks of gastroenteritis. Other foods, including raspberries and salads, have been contaminated before widespread distribution and have subsequently caused extensive outbreaks.

Waterborne outbreaks of norovirus disease in community settings have often been caused by sewage contamination of wells and recreational waters (e.g. swimming areas).

http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus-factsheet.htm

Transmission routes are further described in Module 3.2.

An exercise that may provide an understanding of the magnitude of the diarrhea problem is the calculation of the volume of loose stool (faeces) that norovirus causes in the US (see slide for numbers).

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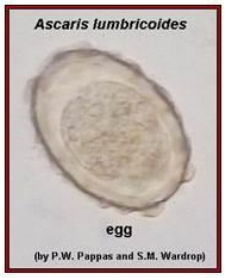
3.1 - 32

Ascaris

- *Ascaris lumbricoides* is one of the largest and most common parasites found in humans
- It is estimated that 10% of the world's population is infected with this nematode
- The adult worms live in the small intestine and eggs are passed in the feces - a single female can produce up to 200,000 eggs each day



Ascaris lumbricoides, fertilized egg. The egg is covered with a thick shell that appears lumpy approximate size = 65 µm in length.

The adult worm. Adult females of this species can measure up to 18 inches long (males are generally shorter).

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

Ascariasis is an infection of the small intestine caused by *Ascaris lumbricoides*, a large roundworm. The eggs of the worm are found in soil contaminated by human faeces or in uncooked food contaminated by soil containing eggs of the worm. A person becomes infected after accidentally swallowing the eggs. The eggs hatch into larvae within the person's intestine. The larvae penetrate the intestine wall and reach the lungs through the blood stream. They eventually get back to the throat and are swallowed. In the intestines, the larvae develop into adult worms. The female adult worm which can grow to over 30 cm in length, lays eggs that are then passed into the faeces. If soil is polluted with human or animal faeces containing eggs the cycle begins again. Eggs develop in the soil and become infectious after 2–3 weeks, but can remain infectious for several months or years.

Children are infected more often than adults, the most common age group being 3–8 years. The infection is likely to be more serious if nutrition is poor. Children often become infected after putting their hands to their mouths after playing in contaminated soil. Eating uncooked food grown in contaminated soil or irrigated with inadequately treated wastewater is another frequent source of infection.

The first sign of infection may be the passage of a live worm, usually in the faeces. In a severe infection, intestinal blockage may cause abdominal pain, particularly in children. People may also experience coughing, wheezing, difficulty in breathing, or fever.

Ascariasis is found worldwide. Infection occurs with greatest frequency in tropical and subtropical regions, and in any areas with inadequate sanitation. Ascariasis is one of the most common human parasitic infections. Up to 10% of the population of the developing world is infected with intestinal worms and a large percentage these infections are caused by *Ascaris*. Worldwide, severe *Ascaris* infections cause approximately 60,000 deaths per year, mainly in children.

Health education providing the following messages reduces the number of infected people:

- avoid contact with soil that may be contaminated with human faeces;
- wash hands with soap and water before handling food;
- wash, peel or cook all raw vegetables and fruits;
- protect food from soil and wash or reheat any food that falls on the floor.

Barriers for disease transmission are further described in Modules 3.3 and 3.4.

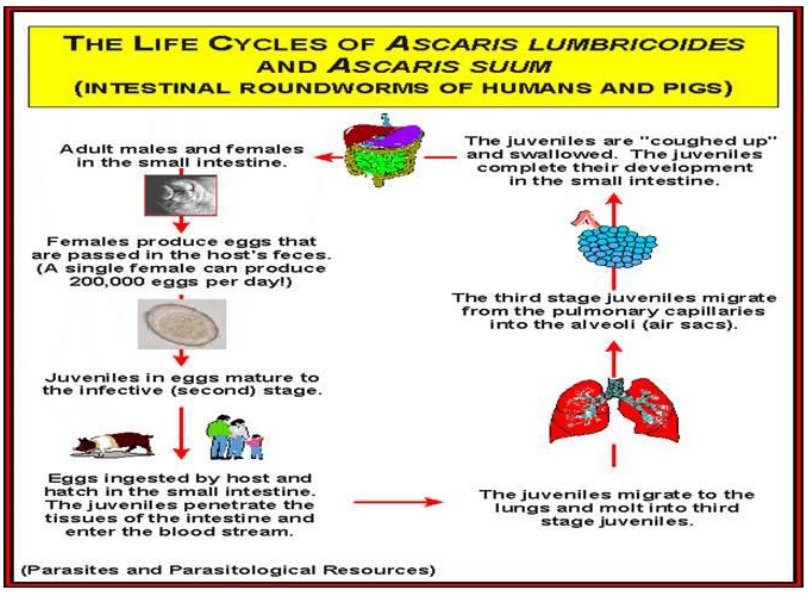
The availability of water for use in personal hygiene as well as proper disposal of human faeces will also reduce the number of cases. Where wastewater is used for irrigation, waste stabilization ponds and some other technologies are effective for decreasing transmission due to food grown in contaminated soil.

http://www.who.int/water_sanitation_health/diseases/ascariasis/en/

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

Ascaris (con´t)

3.1 - 33



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Life Cycle of *Ascaris lumbricoides* and *Ascaris suum*

Ascaris lumbricoides eggs are found in human faeces. After faeces contaminate the soil, the eggs become infectious after a few weeks. Infection occurs when a person accidentally ingests (swallows) infectious *Ascaris* eggs. Once in the small intestines, immature worms hatch from the eggs. The larvae are carried through the lungs and then to the throat where they are swallowed. Once swallowed, they reach the intestines and develop into adult worms. Adult female worms lay eggs that are then passed in faeces; this cycle will take between 2-3 months.

Pigs can be infected with another species of *Ascaris* - *Ascaris suum.* Occasionally, a pig *Ascaris* infection can be spread to humans; this occurs when infectious eggs, found in the soil and manure, are ingested. Infection is more likely if pig feces are used as fertilizer in the garden; crops then become contaminated with *Ascaris* eggs.

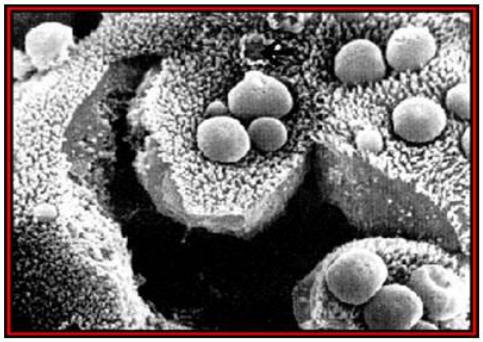
http://www.cdc.gov/ncidod/dpd/parasites/ascaris/factsht_ascaris.htm#what

In research studies, *Ascaris suum*, has been used more extensively than the human *Ascaris*.

Cryptosporidium

3.1 - 34

- *Cryptosporidium* is a small parasite, about 3-5 µm.
- It lives on the surface of the cells lining the small intestine and oocysts are passed in the feces.
- Transmission of the infection occurs via the oocysts.
- Many human infections have been traced to the contamination of drinking water with oocysts from agricultural "run-off" (i.e., drainage from pastures), so it is considered a zoonosis.



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Cryptosporidiosis is a diarrheal disease caused by microscopic parasites of the genus *Cryptosporidium*. Both the disease and the parasite are commonly known as "Crypto."

Many species of *Cryptosporidium* exist that infect humans and a wide range of animals. The parasite is protected by an outer shell that allows it to survive outside the body for long periods of time and makes it very resistant to chlorine disinfection.

While this parasite can be transmitted in several different ways, water is a common method of transmission and *Cryptosporidium* is one of the most frequent causes of waterborne disease (via drinking water and recreational water) among humans in the United States.

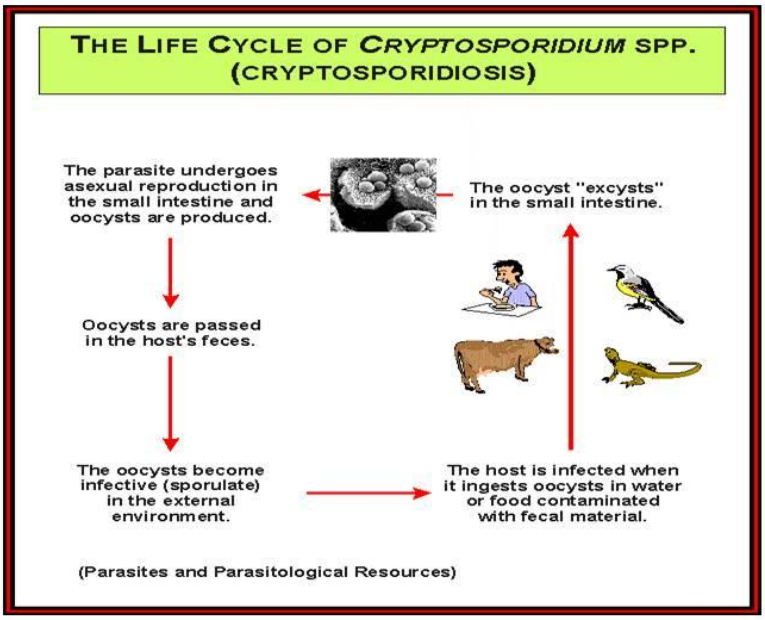
http://www.cdc.gov/crypto/

Since the first reports of human cases in 1976, *Cryptosporidium* has been found worldwide. Outbreaks of cryptosporidiosis have been reported in several countries, the most remarkable being a waterborne outbreak in Milwaukee (Wisconsin) in 1993, that affected more than 400,000 people.

http://www.dpd.cdc.gov/dpdx/HTML/Cryptosporidiosis.htm

Cryptosporidium (con´t)

3.1 - 35



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Life Cycle of *Cryptosporidium* spp

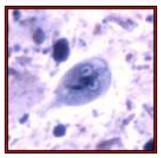
Sporulated oocysts, containing four sporozoites, are excreted by the infected host through feces and possibly other routes such as respiratory secretions. Transmission of *Cryptosporidium parvum* and *C. hominis* occurs mainly through contact with contaminated water (e.g. drinking or recreational water). Occasionally food sources, such as chicken salad, may serve as vehicles for transmission. Many outbreaks in the United States have occurred in waterparks, community swimming pools, and day care centres. Zoonotic and anthroponotic transmission of *C. parvum* and anthroponotic transmission of *C. hominis* occur through exposure to infected animals or exposure to water contaminated by feces of infected animals . Following ingestion (and possibly inhalation) by a suitable host , excystation occurs. The sporozoites are released and parasitize epithelial cells of the gastrointestinal tract or other tissues such as the respiratory tract. In these cells, the parasites undergo asexual multiplication (schizogony or merogony) and then sexual multiplication (gametogony) producing microgamonts (male) and macrogamonts (female) . Upon fertilization of the macrogamonts by the microgametes, oocysts develop that sporulate in the infected host. Two different types of oocysts are produced, the thick-walled variety, which is commonly excreted from the host, and the thin-walled oocyst , which is primarily involved in autoinfection. Oocysts are infectious upon excretion, thus permitting direct and immediate faecal-oral transmission.

Giardia

3.1 - 36

- *Giardia intestinalis* (also known as *Giardia lamblia* or *Giardia duodenalis*
- soil, food, or water that has been contaminated with feces
- Common in both developing and developed areas

- *Giardia lamblia* trophozoites live in the small intestine of the host. Cysts, which are resistant to adverse environmental conditions, are passed in the feces of an infected host, and the next host is infected when it ingests cysts in food or water contaminated with feces.



- The trophozoites adhere closely to the lining of the small intestine, and in heavy infections much of the lining can be covered with trophozoites. The giardiasis symptoms range from none (in light infections) to severe, chronic diarrhea (in heavy infections).

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Giardiasis is caused by a microscopic parasite *Giardia intestinalis* (also known as *Giardia lamblia* or *Giardia duodenalis*). The parasite is found on surfaces or in soil, food, or water that has been contaminated with faeces from infected humans or animals. People can become infected after accidentally swallowing the parasite. *Giardia* causes diarrheal illness, and giardiasis is a common cause of waterborne disease in humans in both developing and developed countries. There are several prescription medicines available to treat *Giardia* infection.
http://www.cdc.gov/ncidod/dpd/parasites/giardiasis/default.htm

3.1 - 37

Features of some gastrointestinal infections

	Morbidity (%)	Excretion (g^{-1} faeces)	Excretion time (days)	ID_{50}
Salmonella	6-80	10^{4-8}	26-51	23 600
Campylobacter	25	10^{6-9}	1-77	900
EHEC	76-89	10^{2-3}	5-12	1 120
Hepatitis A	70	10^{4-6}	13-30	30
Rotavirus	50	10^{7-11}	1-39	6
Norovirus	70	10^{5-9}	5-22	10?
Adenovirus	54	10^{11}	1-14	1.7
Cryptosporidium	39	10^{7-8}	2-30	165
Giardia	20-40	10^{5-8}	28-284	35
Ascaris	15	10^{4}	107-557	0.7

(Westrell, 2004)

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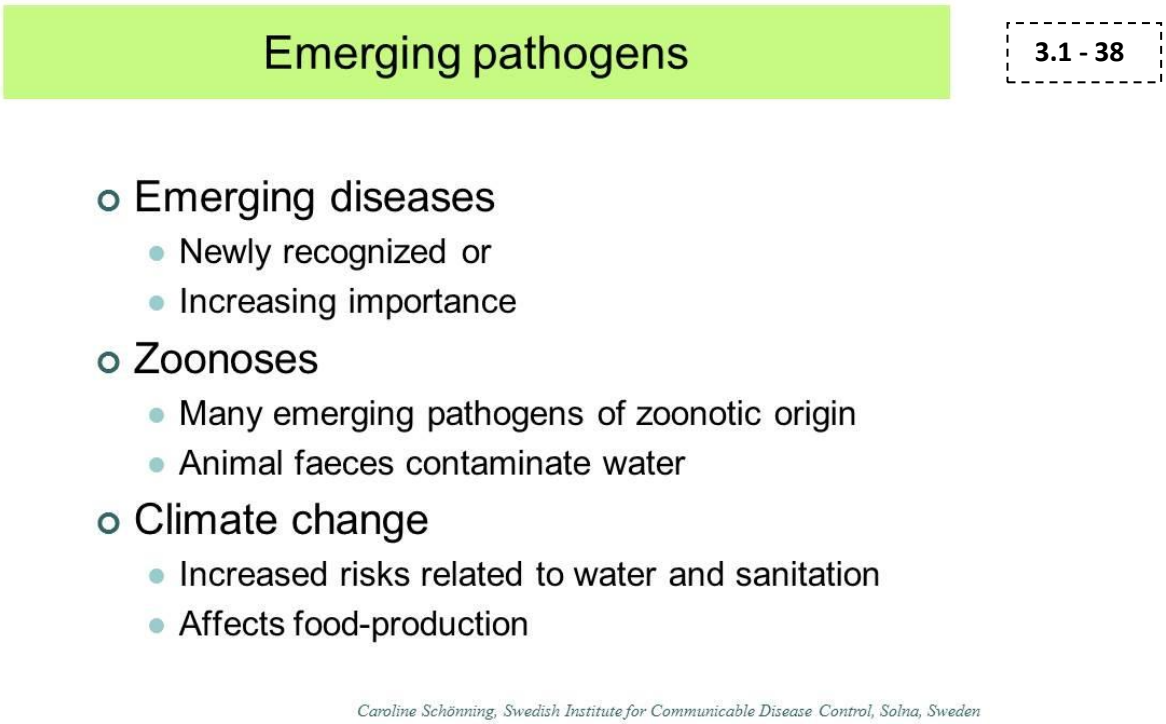
This table shows features of various pathogens that illustrate their differences. These characteristics are of importance when considering the risk the pathogens constitute in water and sanitation systems. “Morbidity” here means the percentage of infected individuals who have symptoms, and this figure can be used to calculate the probability of illness if the probability of infection is known (see Module 3.4). Excretion is a measure of the number of organisms per gram of faeces. These numbers vary substantially between pathogens and may also vary during the course of the infection. The excretion time is listed in days and also varies a lot as can be seen. All these values can be utilised when conducting quantitative microbial risk assessments (QMRA) as further described in Modules 3.4 and 3.5. ID50 is the estimated number of organisms required for 50% of the individuals exposed to this number to become infected (also see slide no 9).

http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-4880



New diseases, including water-related diseases, periodically "emerge" or “re-emerge” either because they are newly recognized or because their importance increases. This may be due to the micro-organisms themselves evolving; to changes in the way we manage water resources and supplies; to changes in the tools and methods used to study the organisms and the health effects they cause; or to changes in the human population itself.

The WHO, the USEPA and other agencies collaborate to address some of these challenges through an initiative on Emerging Issues in Water and Infectious Disease. The initiative leads to the development and publication of state-of-the-art reviews based on wide consultation of international expert.

Zoonoses are diseases caused by microorganisms of animal origin that also infect humans. Zoonoses are of increasing concern for human health; next to pathogens with human-to-human transmission, they are pose the greatest challenges to ensuring the safety of drinking-water and ambient water, now and in the future. Up to 75% of emerging pathogens may be of zoonotic origin. A significant number of emerging and re-emerging waterborne pathogens have been recognized over recent decades. Examples include *E. coli* O157:H7, *Campylobacter*, and *Cryptosporidium*, all of which can be excreted in animal faeces.

It is now generally acknowledged that the global climate is changing, as the earth becomes warmer. Climate change is a significant and emerging threat to public health, and changes the way we must look at protecting vulnerable populations. This change has the potential to affect human health in a number of ways, for instance by altering the geographic range and seasonality of certain infectious diseases. These changes disturb food-producing ecosystems and increase the frequency of extreme weather events such as hurricanes. Thus, these changes may have a large impact on health risks related to water and sanitation systems as well as on food production. How to respond to additional vulnerability is not specifically addressed in this training material. Food and water security will be a major issue as climate change progresses. Water scarcity in itself is a health problem, and water is crucial in food production.

http://www.who.int/water_sanitation_health/emerging/emergingissues/en/

Protozoa and helminths in faecal material

3.1 - 39

- Faecal samples from 120 urine-diverting latrines in KwaZulu-Natal, South Africa
- Varying features – water-filled to dry (normal)
- Analysing for presence of:
  - parasitic protozoa *Giardia* and *Cryptosporidium*
  - helminths *Ascaris lumbricoides*, *Trichuris trichiura* and *Taenia* spp

Picture provided by Teddy Gounden

(Trönnberg et al., 2010)

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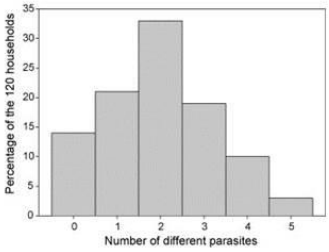
As an example of the prevalence of infectious diseases and risks related to human excreta the following study by Trönnberg et al. (2010) is described (http://dx.doi.org/10.1016/j.trstmh.2010.06.009).

In KwaZulu-Natal outside Durban in South Africa, a large number of urine diverting latrines have been built. In this study samples were collected from the faecal heap collected underneath the diverting toilet. The purpose was to analyse for parasitic protozoa and helminths. In total, 120 household latrines were sampled. The faecal material had varying features, from dry to water-filled.

Protozoa and helminths in faecal material

3.1 - 40

- Parasites
  - 54% positive for Giardia
  - 21% positive for Cryptosporidium
- Helminths
  - 59% *Ascaris lumbricoides*
  - 48% *Trichuris trichiura*
  - 18% *Taenia* spp
- In 73% of the 120 household toilets, one or several types of helminths were found
- Prevalence by family (at least one member infected)
- Supports theory of high prevalence in certain areas
- Treatment needed before use of faeces



(Trönnberg et al., 2010)

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The 120 samples of fresh faecal deposits resulted in the following occurrence of parasites in the family toilets: *A. lumbricoides* (59%), *G. intestinalis* (54%), *T. trichiura* (48%), *Cryptosporidium* spp. (21%) and *Taenia* spp. (18%). In 73% of the 120 household toilets, one or several types of helminths were found. Analysis showed that in 34% of toilets, there was one type of helminth infection A single helminth infection occurred in 34% of the household toilets. Only 14% of the samples were completely negative for parasites. The prevalence can be said to be family-based, meaning that at least one member of the family (the household) was infected at the time of sampling (fresh faeces). The presence of children aged five years or less in the families was found to positively correlate with a higher prevalence of all parasites except *A. lumbricoides*, which showed the opposite. A significant correlation was however only found with respect to the occurrence of *G. intestinalis*.

The occurrence of parasites in 86% of the families implies a risk for further transmission of the pathogens if proper hygiene behaviour is lacking and the toilets are not properly used. The high prevalence of the helminths and parasitic protozoa in the family toilets demonstrates an endemic state of infection in the communities. Other studies report high prevalence in communities lacking municipal sewers and a higher prevalence of *Cryptosporidium* spp. has been reported for communities with unsafe drinking water sources, which supports the potential link between parasite endemicity and poor water and sanitation. The findings of the present study highlight the need for proper containment of excreta to reduce the likelihood of further transmission of parasites when hygiene resources are limited and socioeconomic standards are low.

The numbers for excretion (densities in faeces) found in literature are higher than the quantities of ova and (oo)cysts found in the sampled excreta from the vaults in this study. This implies that an overestimation of the risk will be made if values, as reported in the literature, are used as input parameters in a risk assessment, and thus shows the value of using local data in quantitative risk assessments. The families in these areas are currently not reusing the faecal material after storage, but health protection measures still need to be applied in the system. These measures are needed regardless of whether the faeces are used or buried (e.g. treatment and personal protective equipment, see Module 3.4).