

# Chapter 1

## Introduction

Improving health is one of the main goals of water and environmental sanitation interventions. Despite this, many aid and development workers working in the field of water and environmental sanitation have only a limited knowledge of the infections they try to prevent. Although the relevant information does exist, it is often scattered in specialised literature and rarely finds its way into the field.

This manual addresses this problem by presenting information to aid and development workers on these infections in relation to the interventions that these workers control: water supply, sanitation, drainage, solid waste management, and vector control.

### 1.1 Definitions of commonly used terms in this manual

**Water supply** is the means by which people are provided with water for domestic use. This is water used for drinking, cooking, washing, and other domestic activities like watering gardens or water for domestic animals.

**Sanitation** refers to all aspects of excreta disposal (human and animal, faeces and urine). It includes sanitary structures (e.g. latrines); material needed for the proper operation and use of the structures (e.g. water, soap); and the human behaviour and attitudes relating to excreta and its disposal.

**Environmental sanitation** means *drainage* (how unwanted water is disposed of); *solid waste management* (how refuse is dealt with); and *vector control* (measures taken to reduce the risks of disease posed by vectors).

**Water and environmental sanitation** means water supply, sanitation, drainage, solid waste management, and vector control. These are called the *components* of water and environmental sanitation projects. These components have physical aspects (e.g. latrines), as well as behavioural aspects (e.g. keeping latrines clean). Water and environmental sanitation is often shortened to *WES* in this manual.

**Infection** usually means the entry and development of organisms (e.g. virus, bacterium) in a host (human or animal) (Benenson, 1995). In this manual we use the word *infection* for the development in a host of an organism(s) whose transmission and/or prevention are influenced by WES.

**Disease** is a broad term normally used for any malfunction of the body resulting from a cause other than injury. An infection is only a communicable or infectious disease if it results in illness. Although, strictly speaking, it is not correct to use disease and infection synonymously (most infections covered in this manual can result in infection without symptoms), we have done so here to improve readability.

Please note: Throughout this manual, Dracontiasis is referred to as Guinea-worm, the commonly used name for the disease.

### 1.2 Who this manual is for

This manual has been produced primarily for non-medical aid and development workers working in water and environmental sanitation at field level. Nevertheless, anyone working in WES, or in the prevention of infections related to WES, may find this book useful.

Aid and development workers operating at various stages of the project cycle will find this manual useful. Whether you need to assess the health risks in an existing situation; write, or assess, a project proposal; or implement an intervention, you will find relevant information in this book. You do not need to have extensive knowledge, of or experience in WES or in disease to be able to use this manual.

### 1.3 Scope of the manual

This manual covers infections that occur in all developing countries, and will be useful for both emergency and longer term development projects. It can be used in both urban and rural situations, and with settled as well as displaced populations such as internally displaced people and refugees.

The various components of WES up to the level at which aid and development workers in the field usually work are covered. We focus on appropriate technology options. The specific health problems related to industries, mines, large hospitals, abattoirs, or sewage treatment plants are not addressed.

Although housing plays an important role in the prevention of disease, housing issues have not been addressed here as the improvement of housing will not usually be the responsibility of the WES specialist.

### **1.4 Structure of the manual**

While some readers will want to study subjects in depth, many fieldworkers need relevant, concise information which is accessible, and easy to work through. This manual, therefore, provides information in two ways and has two parts.

Part 1 is comprised of information in chapters as summarised in Section 1.4.1 below. Part 2 is comprised of annexes: information in list and tabular form as outlined in Section 1.4.2.

#### **1.4.1 Part 1**

##### **Chapter 2: Disease and disease transmission**

This chapter looks at how the infections related to WES are transmitted. The elements of the transmission cycle of disease are presented, along with important related issues. In addition, this chapter categorises the infections linked to WES into groups with similar transmission cycles.

##### **Chapter 3: Disease in the population**

In this chapter we introduce some basic concepts about the dynamics of disease in a population, and examine endemic and epidemic occurrence of disease, epidemiology, and mortality and morbidity rates.

##### **Chapter 4: Water and environmental sanitation projects**

Chapter 4 looks at the background to WES projects. We consider why these projects are necessary, and what they try to achieve. The WES project cycle is also described. In addition, several issues relating to the impact and sustainability of interventions are presented. The chapter ends with an examination of the link between health, poverty, and development.

##### **Chapters 5 to 8**

In these chapters we introduce the components of WES – domestic water supply, sanitation, drainage, and solid waste management – along with the health issues associated with each component.

We do not specifically look at vector control here, as this subject would be too vast to cover adequately. The role that water supply, sanitation, drainage, and solid waste play in vector control is, of course, important, and this is covered in the relevant chapters. Although we do not cover vector control in its own chapter, we have included all vector-borne diseases of importance in Annexe 1, and Annexe 3 presents summary tables on both vector-borne infections and vectors and their control.

## **1.4.2 Part 2**

### **Annexe 1: Properties of infections related to WES**

In this annexe we list all the common infections related to WES with their properties relevant to WES specialists. We cover over 85 infections in a standard format.

### **Annexe 2: Occurrence, transmission and control of infections related to WES (excluding vector-borne infections)**

Annexe 2 presents information on the occurrence of infections, whether it has animal vectors, and measures of control in the form of tables. Vector-borne diseases are covered in Annexe 3.

### **Annexe 3: Vector-borne infections: their vectors and control**

In this annexe we present tables which link infections to vectors, vectors to properties, and vectors to methods of control.

### **Annexe 4: The chlorination of drinking water**

Here we look at how to determine the demand of chlorine in water, and how to calculate how much chlorine to add to large water volumes.

### **Annexe 5: Sizing pits for latrines and determining their infiltration capacity**

This annexe explains how to size the pit for a latrine, and how much liquid the pit can cope with.

### **Annexe 6: Designing a simple drainage system for stormwater**

Here we present a method for estimating how much stormwater a catchment area will produce, and how to size a drain which has to cope with this flow.

### **Annexe 7: Minimum standards in emergencies**

In this annexe we present the basic needs of healthy people to survive, and the minimum standards of WES service that have to be provided to people in an emergency situation.

## **1.5 How to use the manual**

To understand better the issues relating to disease transmission, the dynamics of disease in the population, and WES projects and WES components, read Chapters 2 to 7 from start to end. Many readers, however, will not be in a position to read through the text in this way, so the manual has also been designed to be used as a reference book, with information listed in the table of contents and the index.

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The manual is also structured to allow the reader to extract information by disease, by project, or by the components of WES.

### **The diseases**

Information on individual infections is presented in Annexe 1.

More than 85 infections are covered in 60 individual sections. All sections have the same format, although some less relevant or less important infections are only summarised. Readers can find important information on each disease, such as distribution of the infection, severity of the disease, how transmission occurs, whether the infection is a risk in a disaster and preventative measures.

This information is important to know how to reduce an existing problem, or how to prevent the infection from becoming a problem in the future.

Annexes 2 and 3 present summary information on different infections. This allows the reader to verify quickly whether preventative measures are likely to be effective against specific diseases, and to associate different infections with specific preventative measures.

If a more general perspective on disease transmission is required, or information on the dynamics of disease in the population, Chapters 2 and 3 will be useful. In addition, these chapters will give more background information on issues raised in the other sections on diseases.

### **The WES project**

Chapter 4 is an introduction to WES projects, and presents the issues that should be considered to improve impact and sustainability.

Chapters 5, 6, 7, and 8 briefly present some issues other than health which are associated with components of WES and which should be taken into consideration when making a project proposal.

### **The components of WES**

Readers who want general information on water supply, sanitation, drainage, solid waste management, or vector control can find this in Chapters 5, 6, 7 and 8 and Annexes 3, 4, 5, 6, and 7. In these chapters, the issues related to health are presented, which will be useful for people who have to assess the health risks in an area, who want to know whether certain components would be effective in reducing the health risk, or who have to assess whether a proposed component would be the most effective measure. In these chapters and annexes we look at the

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practical aspects relating to the components which will help workers who have to plan, design, or implement interventions, or who have to assess whether existing structures or services are adequate.

Although this book has not been designed as a technical manual, technical information important to the proper functioning of WES components is included to avoid the common frustration experienced by readers of such texts: 'They tell us what to do, but not how to do it!'. The technical information is not complete, but may be useful, for example, to address rapidly specific problems that arise in an emergency such as the chlorination of drinking-water, the design of sanitary structures, or the removal of stormwater from a refugee camp. In addition, an annexe has been included which presents the priorities and minimum standards of WES in emergencies in summary form.

## Chapter 2

### **Disease and disease transmission**

An enormous variety of organisms exist, including some which can survive and even develop in the body of people or animals. If the organism can cause infection, it is an infectious agent. In this manual infectious agents which cause infection and illness are called pathogens. Diseases caused by pathogens, or the toxins they produce, are communicable or infectious diseases <sup>(45)</sup>. In this manual these will be called disease and infection.

This chapter presents the transmission cycle of disease with its different elements, and categorises the different infections related to WES.

#### **2.1 Introduction to the transmission cycle of disease**

To be able to persist or live on, pathogens must be able to leave an infected host, survive transmission in the environment, enter a susceptible person or animal, and develop and/or multiply in the newly infected host.

The transmission of pathogens from current to future host follows a repeating cycle. This cycle can be simple, with a direct transmission from current to future host, or complex, where transmission occurs through (multiple) intermediate hosts or vectors.

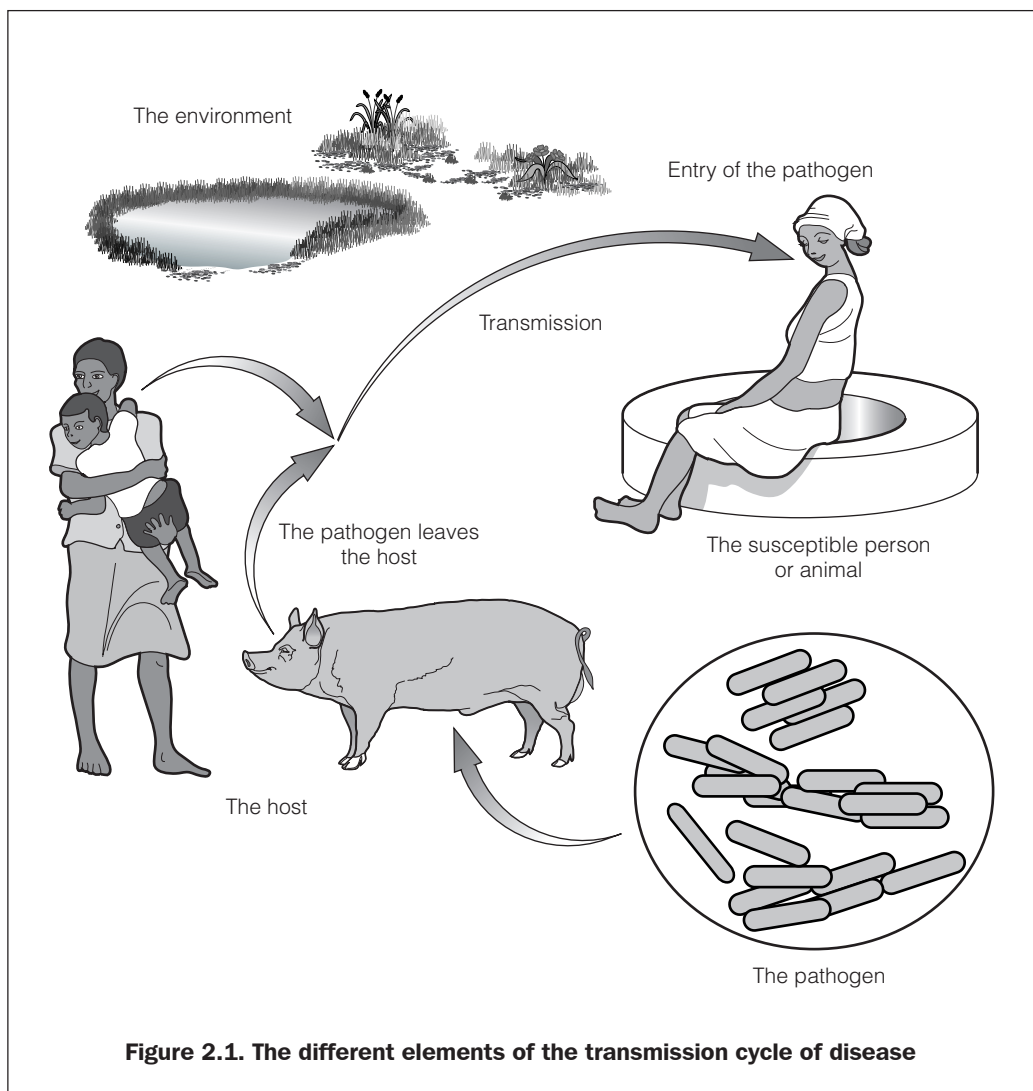
This cycle is called the transmission cycle of disease, or transmission cycle. The transmission cycle has different elements:

- The pathogen: the organism causing the infection
- The host: the infected person or animal 'carrying' the pathogen
- The exit: the method the pathogen uses to leave the body of the host
- Transmission: how the pathogen is transferred from host to susceptible person or animal, which can include developmental stages in the environment, in intermediate hosts, or in vectors

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- The environment: the environment in which transmission of the pathogen takes place.
- The entry: the method the pathogen uses to enter the body of the susceptible person or animal
- The susceptible person or animal: the potential future host who is receptive to the pathogen

To understand why infections occur in a particular situation, and to know how to prevent them, the transmission cycles of these infections must be understood. The rest of this chapter looks at the elements of the transmission cycle in more detail.





## 2.2 The pathogen

The pathogen is the organism that causes the infection.\* Specific pathogens cause specific infections. Cholera is caused by the bacterium *Vibrio cholerae*, for example, and Leishmaniasis is caused by different species (spp.) of the protozoa *Leishmania*.

Specific infections also have specific transmission cycles. To be able to react appropriately to health problems in a population, the specific infection causing the problems must be known. Identification of the infection will usually be done by medical personnel.

Different categories of pathogens can infect humans. The pathogens causing the diseases covered in this manual include viruses, bacteria, rickettsiae, fungi, protozoa, and helminths (worms). All pathogens go through a lifecycle, which takes the organism from reproducing adult to reproducing adult. This cycle includes phases of growth, consolidation, change of structure, multiplication/reproduction, spread, and infection of a new host. The combination of these phases is called the development of the pathogen.

Two terms are commonly used to describe pathogens leaving the host through faeces or urine: latency and persistence.

After excretion, a latent pathogen must develop in the environment or intermediate host before a susceptible person or animal can be infected. During the latent period the pathogen is not infectious. A non-latent pathogen does not need to go through a development, and can cause infection directly after being excreted.

Persistency describes how long a pathogen can survive in the environment. A persistent pathogen remains viable for a long period outside the host (perhaps months), while a non-persistent pathogen remains viable for only a limited period<sup>(6)</sup> (days, or weeks).

Active immunity is the resistance the person or animal develops against the pathogen after overcoming infection or through immunisation (vaccination).<sup>(45)</sup> Depending on the pathogen, the effectiveness of active immunity often decreases over time.

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\* It is important to realise that not all infections will result in disease. While a pathogen may cause illness in one person, it may be killed or cause asymptomatic infection in another.

Usually immunity only develops against the specific pathogen that caused the infection. If there are different types (serotypes or strains) of the same pathogen (e.g. in dengue fever and scrub typhus), immunity will often only develop against the particular type which caused the infection. The person or animal can still develop the illness when infected with another serotype or strain of the pathogen<sup>(3)</sup>.

Table 2.1 presents the different categories of pathogenic organisms with some of their characteristics, including latency, persistence, and immunity. The information is general, and exceptions can occur.

## 2.3 The host

The host is the person or animal infected by the pathogen. The importance of the host in the transmission cycle is its roles as both reservoir and source of pathogens.

There are two types of host: definitive and intermediate host. The definitive host is the person or animal infected with the adult, or sexual, form of the pathogen. In the infections covered here, people are usually the definitive host. To keep things simple the definitive host is called just ‘the host’.

The intermediate host is an animal or person infected by a larval, or asexual, form of the pathogen<sup>(3)</sup>. Cysticercosis and hydatid disease are the only infections covered here for which people are the intermediate host. Where intermediate host is meant, this term is used. Of the infections covered here, only helminths have both definitive and intermediate hosts. All other pathogens only have definitive hosts, although vectors function technically as intermediate hosts for protozoa.

### ***Zoonosis: transmission from animal to person***

Some pathogens are specific to humans, others to animals. Many pathogens are less specific and can infect both people and animals. Infections that can naturally be transmitted from animal to person are called zoonoses<sup>(3)</sup>. Zoonoses are very common; over half of the infections covered in this manual are zoonoses. Many of these infections normally occur in an animal cycle, with people being infected by chance.

The problem with zoonoses is that a continuous reservoir of pathogens exists outside humans. Even if all human infections were cured and transmission to people stopped, the presence of an animal reservoir would remain a continuous risk to people.

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**Table 2.1. Categories of pathogenic organisms and their characteristics**

<b>Pathogen</b>	<b>Description</b>	<b>Latency</b>	<b>Persistence</b>	<b>Additional information</b>
<b>Virus</b>	Particles invade living cells. The pathogen needs structures in these cells to reproduce. <sup>(45)</sup>	The pathogens are non-latent.	Viruses can survive for months in tropical temperatures. <sup>(28)</sup>	Where vector-borne, transmission to offspring is possible <sup>(3)</sup> . The immunity is often long-lasting. <sup>(73)</sup>
<b>Rickettsiae</b>	Organisms resemble bacteria. <sup>(45)</sup> . However, similar to viruses, the pathogen needs to develop inside the cells of the host. <sup>(2)</sup>	n/a	n/a	Transmission of the pathogen to the offspring of the vector occurs. <sup>(73)</sup> . The immunity is usually long-lasting. <sup>(3)</sup>
<b>Bacteria</b>	Bacteria are single cell organisms. They are considered more primitive than animal or plant cells. <sup>(45)</sup>	The pathogens are non-latent.	Persists up to several weeks. <sup>(16,73)</sup> . Can multiply outside the host. <sup>(3)</sup>	The immunity developed is often incomplete or short-lived. <sup>(3)</sup>
<b>Fungi</b>	A group of organisms which include yeast, moulds, and mushrooms. <sup>(45)</sup>	n/a	n/a	The duration of the immunity is variable. <sup>(3)</sup>
<b>Protozoa</b>	Protozoa are single cell organisms. <sup>(45)</sup>	The pathogens are non-latent.	Forms a resistant cyst which can survive for months. <sup>(3,44)</sup>	The immunity is only maintained by repeated infections or vaccinations. <sup>(73)</sup>
<b>Helminths (worms)</b>	Helminths are worms (roundworms, flukes or tapeworms) <sup>(45)</sup> . Often male and female must meet in host to reproduce, and sometimes they multiply in intermediate hosts.	The pathogen is latent. It often has a complex lifecycle with a development in the environment or intermediate hosts. <sup>(73)</sup>	The pathogen is persistent and some may survive for years in the environment. <sup>(3, 16)</sup>	Usually no immunity is built up against the pathogen. <sup>(3)</sup>

n/a: Not applicable as the pathogens are not excreta-related.

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Prevention of zoonoses often includes control of animal hosts. This is possible by reducing the number of hosts (e.g. controlling rats), immunising domestic animals, or avoiding unnecessary contact with host animals.

### ***Carriers: hosts without obvious illness***

A person or animal who develops an illness is an obvious example of a host. It is very common, however, for infections to occur without the disease developing. The person or animal infected can potentially spread the pathogen, but does not show clear symptoms <sup>(8)</sup>. The symptoms may be mild, or may be completely absent.

These hosts are called carriers, or asymptomatic carriers. Table 2.2 shows some infections that are frequently mild or asymptomatic. The host can be infectious for a short period in transient carriers, or over a prolonged period in a chronic carrier <sup>(3)</sup>. Incubating carriers have been infected and can spread the pathogen, but do not yet show the symptoms of the illness. Convalescent carriers continue to spread the pathogen even though they have recovered from illness.

In many infections carriers play an important role in transmitting the pathogen. It is usually not possible to identify asymptomatic carriers <sup>(73)</sup>, and unless the family and other close contacts of the sick person or even the whole population can be treated, carriers will remain a threat to the health of those surrounding them.

**Table 2.2. Examples of infections with asymptomatic carriers**

<b><i>Infection</i></b>	<b><i>Asymptomatic infections</i></b>
Bacillary dysentery	common <sup>(3)</sup>
Cholera (El Tor)	only 1 in 30-50 infections develops illness <sup>(16)</sup>
Giardiasis	1 in 2-4 infections develops illness <sup>(44)</sup>
Polio	very common
Typhoid fever	very common <sup>(73)</sup>
Schistosomiasis	very common <sup>(16)</sup>
Hookworm	very common
Yellow fever	common <sup>(3)</sup>
Japanese Encephalitis	only 1 in 1,000 infections develops illness <sup>(44)</sup>
Filariasis	very common
Malaria	common <sup>(3)</sup>
River blindness	common <sup>(2)</sup>
Plague	common during epidemics <sup>(73)</sup>

### ***Other reservoirs of pathogens***

Besides hosts, there are several other pathogen reservoirs that can play a role in the transmission of disease. Some pathogens are very resistant, and can survive in the environment for considerable time. Though this will normally be an exception, roundworm eggs can remain viable in soil for years <sup>(3)</sup>.

Intermediate hosts may be important reservoirs of pathogens, and several helminths can even multiply in the intermediate host.

Vectors are usually infectious for life, and several pathogens can be transmitted to the offspring of the vector over several generations <sup>(2)</sup>. A soft tick, for example, can survive for more than five years and can pass to its offspring the pathogen which causes tick-borne relapsing fever <sup>(73)</sup>.

Some pathogens can live their entire lifecycle outside the host. These include threadworm and several faecal-oral bacteria which cause bacillary dysentery, (para)typhoid, and salmonellosis <sup>(3)</sup>.

Animal hosts, asymptomatic carriers, and other potential reservoirs of pathogens can be important sources of infection, and this must be taken into account when trying to control disease. The whole population at risk may have to be treated, or animal hosts controlled. With several diseases these preventive measures will have to be maintained over a long period before a reduction in the occurrence of the infection will be noticeable.

## **2.4 Transmission of disease**

To survive as a species, pathogens must infect new people or animals. To do this, they must leave the body of the host, find their way to a new susceptible person or animal, and enter the body of that person or animal. As the exit, transmission, and entry of the pathogens are closely associated, we will cover them together.

Water and environmental sanitation interventions that aim to improve the health of a population usually try to reduce the risk of transmission of infection. To do this appropriately, the WES specialist needs to be familiar with the pathogens' transmission route(s). It is this understanding that enables the specialist to determine which control measures will be most effective in a particular situation.

As many infections are linked to WES, it is useful to categorise the different diseases.

For a water and sanitation specialist the most useful categorisation is based on the transmission cycles of the infections. Generally speaking, diseases with similar transmission cycles can be controlled by similar preventive measures, and will occur in similar environments.

The infections are categorised and their transmission routes described at the same time. More information on the transmission routes and potentially effective preventive measures of specific diseases can be found in Annexe 1.

Some terms relating to the transmission or classification of infections are defined here:

**Food-borne infections:** infections which can be transmitted through eating food containing the pathogen.

**Vector-borne infections:** infections transmitted through vectors. We use vector-borne infections only for infections with a *biological vector*, that is a vector in which the pathogen goes through a development before further transmission is possible (e.g. mosquitoes, tsetse fly, body louse). We do not classify as vector-borne those infections which are transmitted by *mechanical vectors*, that is the animal is only a vehicle for transporting the pathogen (e.g. domestic flies, cockroaches).

**Water-borne infections:** infections which can be transmitted through drinking-water which contains the pathogen.

**Water-washed infections:** infections caused by pathogens whose transmission can be prevented by improving personal hygiene.

Infections can have either direct or indirect transmission routes.

### **2.4.1 Infections with direct transmission**

A pathogen with a direct transmission route can infect a susceptible person or animal immediately after leaving the host. The pathogen does not need to develop in the environment, in an intermediate host, or in a vector.

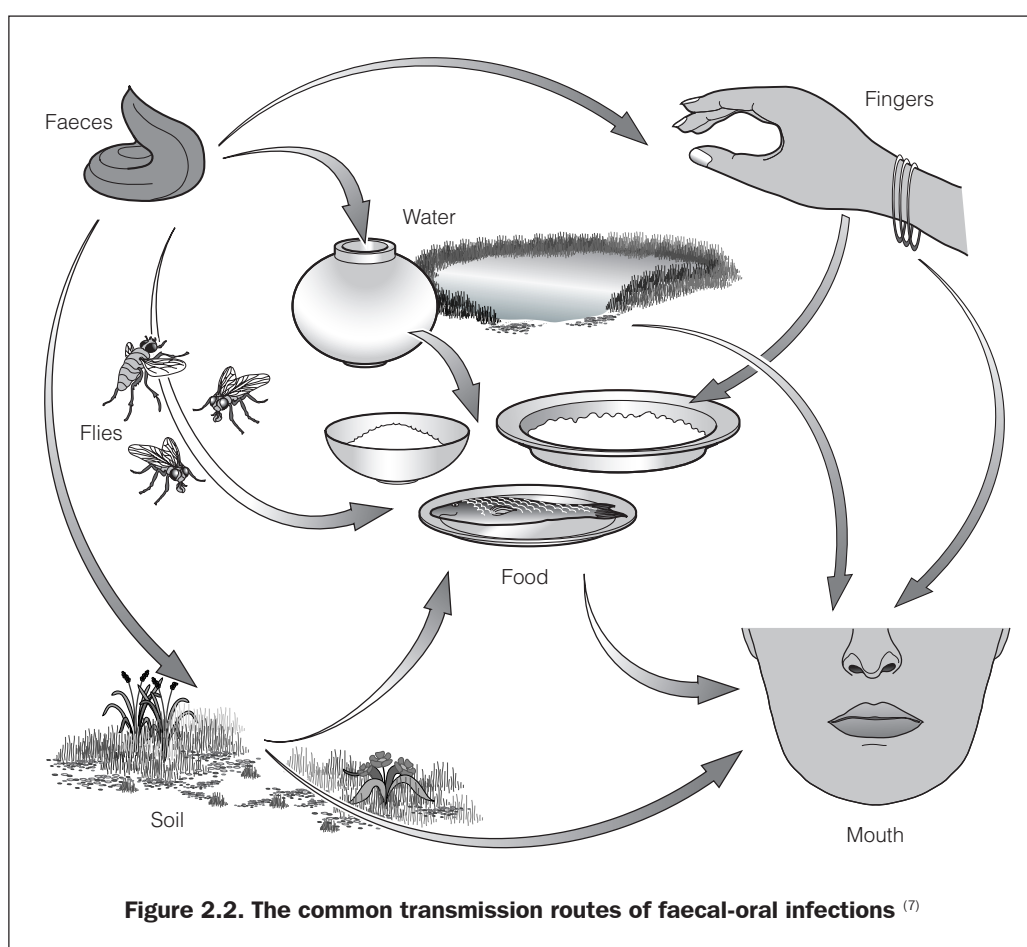
In faecal pathogens these are the non-latent infectious agents.

This group contains three disease-groups: faecal-oral infections, leptospirosis, and infections spread through direct contact.

### 2.4.1.1 Faecal-oral infections

These pathogens leave the host through faeces, and enter the susceptible person or animal through ingestion. Transmission occurs mainly through direct contact with contaminated fingers; food contaminated directly with excreta, contaminated hands, domestic flies, soil, or water; contaminated drinking-water; or contaminated soil. Faecal-oral infections are food-borne, water-borne, and water-washed. As faecal-oral infections are transmitted directly, any route that will take matter polluted with faeces directly or indirectly to somebody's mouth could potentially transmit the pathogen. Figure 2.2 shows some common transmission routes of faecal-oral infections.

Some of these infections have mainly animal hosts, while others are limited to humans. Faecal-oral infections include diarrhoeal diseases such as cholera and bacillary dysentery, typhoid, hepatitis A, and poliomyelitis.



**Figure 2.2. The common transmission routes of faecal-oral infections <sup>(7)</sup>**

### **2.4.1.2 *Leptospirosis***

The main reservoir of leptospirosis is normally rats, though many other animals can potentially transmit the infection. The pathogen leaves the animal host through urine. People are usually infected through direct skin contact with water, moist soil, or vegetation contaminated with urine from infected animals. Other ways of transmission are direct contact with body tissues of infected animals or ingesting food contaminated with urine. Transmission from person to person is rare <sup>(3)</sup>.

### **2.4.1.3 *Infections of direct contact***

All the diseases covered in this manual that fall into this category are infections which affect the skin or eyes. Pathogens are present on the skin or in the discharges of affected body parts or eyes. The pathogens are transmitted directly through contaminated hands, clothes, domestic flies, or any other contaminated material.

The pathogen enters the body through skin or mucous membranes such as the eyes. These infections are associated with poor personal hygiene and are water-washed.

Few of these infections have animal hosts. The diseases in this category include conjunctivitis, trachoma, yaws, and scabies.

## **2.4.2 *Infections with indirect transmission***

A pathogen with an indirect transmission route must go through a development phase outside the host before it can infect a new susceptible person or animal. This development will take place in a specific intermediate host, vector, or type of environment.

This need to go through a particular organism or environment gives the transmission route a focus, which preventive measures can target, for example by vector control or improved food preparation.

In the faecal pathogens these are the latent infectious agents.

The disease-groups with indirect transmission are soil-transmitted helminths, water-based helminths, beef/pork tapeworm infection, Guinea-worm infection, and vector-borne infections.



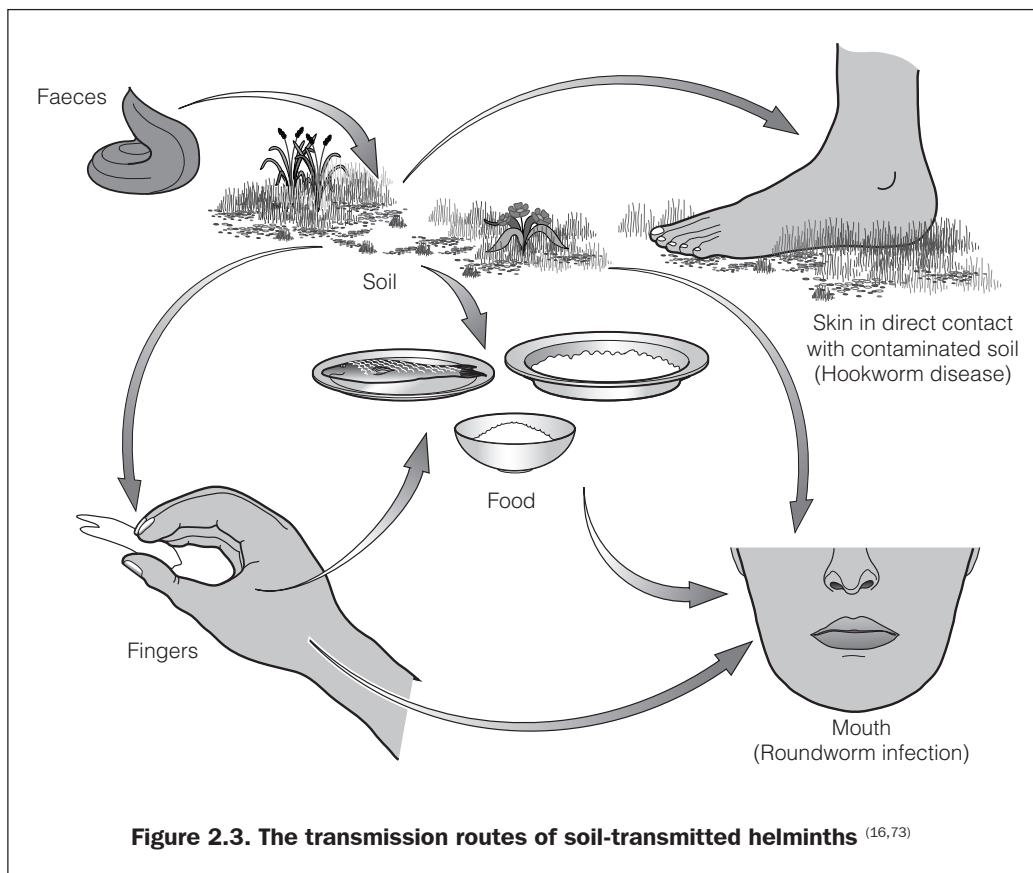
#### 2.4.2.1 *Soil-transmitted helminths*

These worms leave the body through faeces as eggs or larvae. After excretion they have to develop in soil. They can be further divided based on how the pathogen enters the human body.

**Entrance by penetration of the skin:** the pathogen enters the body through skin which is in direct contact with contaminated soil. This is the method used by hookworms and threadworms.

**Entrance by ingestion:** if either contaminated soil, or food or hands contaminated with polluted soil come into contact with the mouth, the pathogen can be transmitted. These infections can be food-borne and water-washed. This method is used by roundworms and whipworms.

The infections covered here do not have animal hosts. Figure 2.3 presents the transmission routes of the soil-transmitted helminths.



#### **2.4.2.2 Water-based helminths**

These pathogens leave the body through excreta. The infectious agents must develop in intermediate hosts living in freshwater. The transmission of these infections is therefore only possible if excreta containing the pathogens reaches fresh surface water in which there are suitable intermediate host(s). Based on transmission cycle, this category can be sub-divided in two groups:

**Schistosomiasis.** After excretion, the pathogen infects a freshwater snail, in which it develops and multiplies. The snail releases the pathogens into the water, and people are infected when these pathogens penetrate skin which is in direct contact with infected freshwater. Only one type of schistosomiasis (which occurs only in Asia) has an important reservoir in an animal host; all other types have people as the only host of importance.

**Water-based helminths** with two water-based intermediate hosts. The first intermediate host is a freshwater snail or copepod. The second intermediate host is a freshwater plant, fish, or crabs/crayfish. The intermediate hosts are specific to the pathogen. These infections are food-borne and people become infected when they eat the second intermediate host without properly cooking it. All these infections affect both animals and people. These diseases include opisthorchiasis, clonorchiasis, and lung fluke disease.

The transmission routes of the water-based helminths are presented in Figure 2.4.

#### **2.4.2.3 Beef/pig tapeworm infection**

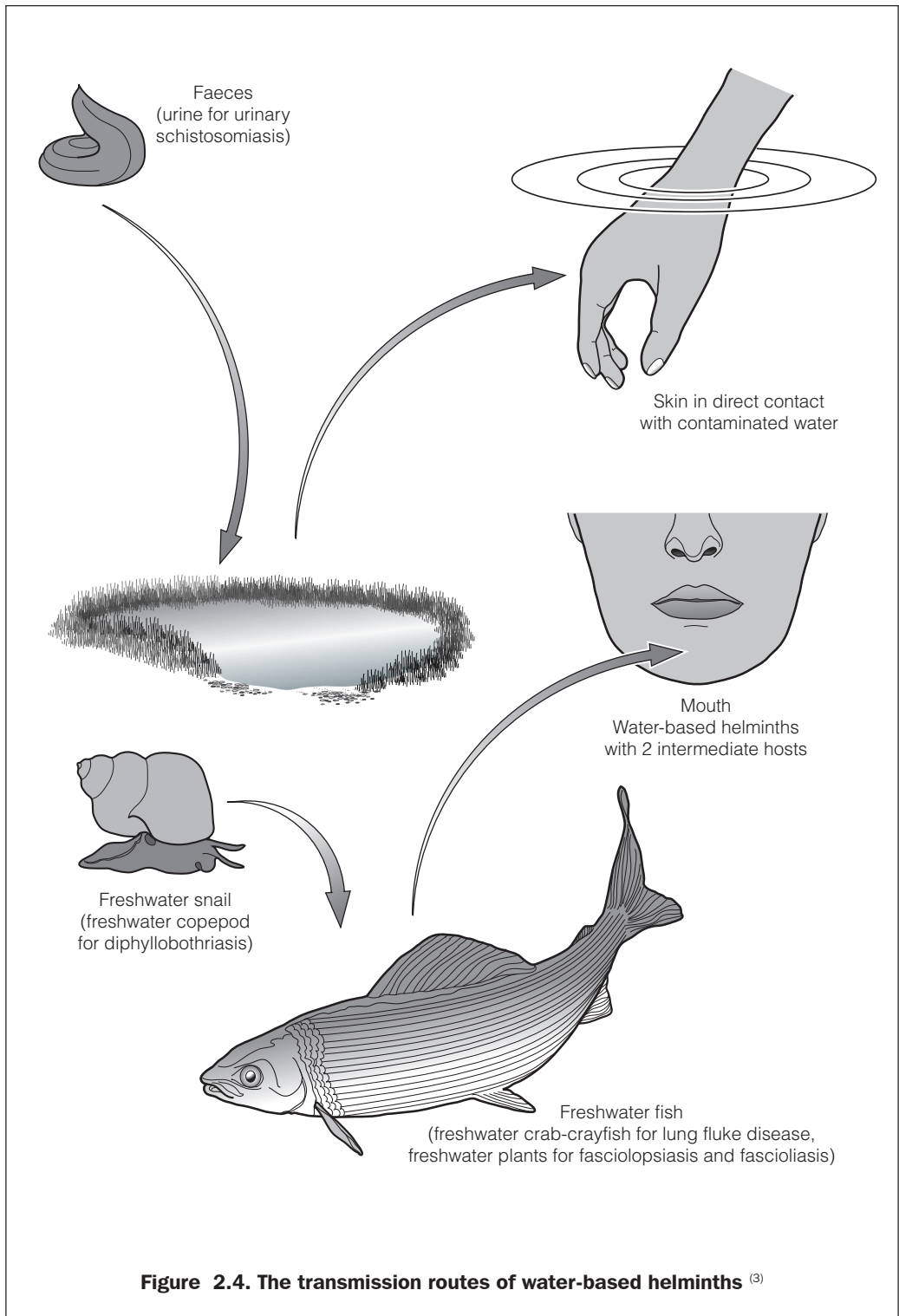
The pathogens leave the person through faeces. The excreted eggs then have to be ingested by either cattle or pigs. Once the pathogen is ingested by the animal, it will develop in the body of the cow or pig. The infections are food-borne and people become infected when they eat undercooked beef or pork containing the pathogen. People are the only hosts to the infection.

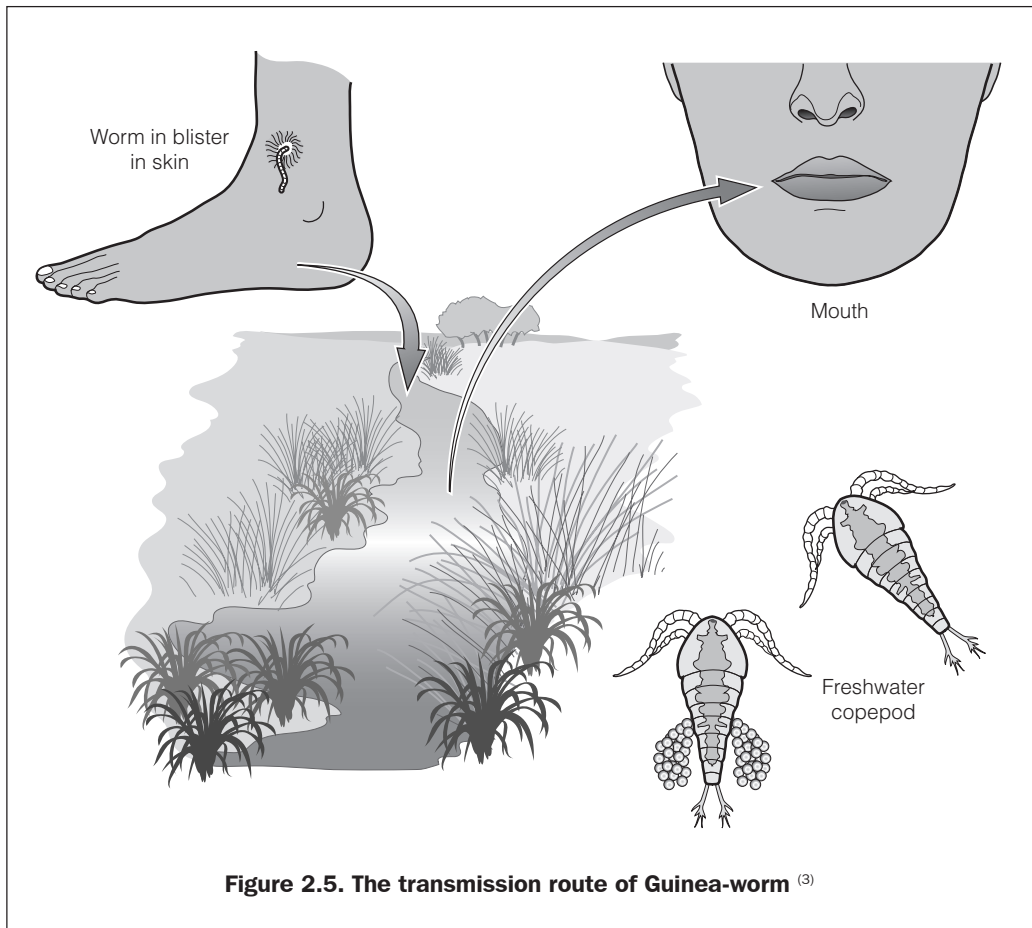
A dangerous complication called cysticercosis is possible when people ingest the eggs of the pig tapeworm. The pathogen will form cysts throughout the person's body. Transmission of this infection is like faecal-oral infections.

#### **2.4.2.4 Guinea-worm**

In this infection the pathogen, a large worm, creates a blister on the person's skin, which erupts when it comes into contact with water, releasing the worm's larvae. These larvae then infect a copepod (*Cyclops*), in which it develops. The disease is water-borne. People become infected by drinking water containing *Cyclops*, and

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are the only host to this infection. Figure 2.5 shows the transmission route of Guinea-worm.

## 2.4.2.5 Vector-borne diseases

These infections are transmitted by vectors. Vectors are arthropods (insects, ticks, or mites) which can transmit infections from host to future host <sup>(73)</sup>. The pathogen exists in the blood or skin of the host. The vector becomes infected when it feeds on a host. The pathogen develops and multiplies inside the vector, which then becomes infectious. People are usually infected through the bite of an infectious vector, though other ways of entry are possible. With several vector-borne diseases animal hosts are important reservoirs. Vector-borne diseases include yellow fever, malaria, sleeping sickness, plague, epidemic louse-borne typhus fever, and louse-borne relapsing fever.

## 2.5 The environment

The environment is everything that surrounds the pathogen in its transmission from host to susceptible person or animal. Obviously the environment is a vast subject, and we can only look at some of the more important environmental factors here.

Interventions which involve WES will often modify the environment to try to reduce the transmission risk.

The environmental factors that we will look at here are climate, landscape, human surroundings, and human behaviour. Environmental factors are often associated, for example higher altitudes result in lower temperatures, landscapes are formed by the climate.

### 2.5.1 The climate

The climate and its seasonal changes play an important role in disease transmission. The presence of vectors and intermediate hosts often depends on rain and temperature.

The climatological requirements of the vector or intermediate hosts can predict whether an infection is likely to be a problem in an area. Malaria, for example, will normally not occur in temperatures below 16°C and infection is thus unlikely at altitudes above 2,000 metres.

In general, direct sunlight, a dry environment, and high temperatures will reduce the survival times of pathogens in the environment.

Conditions may not be suitable to transmission year round, and many infections are seasonal, occurring when the environment is favourable to transmission. Mosquito-borne infections, like malaria and yellow fever, are linked to the rainy season <sup>(16,44)</sup>. The occurrence of diarrhoeal diseases often increases with the first rains after the dry season, as faecal pollution is washed into rivers. Ponds which disappear in the dry season may in the wet season contain water with snails that will transmit schistosomiasis <sup>(73)</sup>.

The climate influences human behaviour. In cold climates people will crowd together and wear more clothing. If this is combined with poor personal hygiene the body-louse, vector of louse-borne typhus fever and louse-borne relapsing fever, can thrive.

In warmer climates children are also likely to play in surface water, where they can be infected with schistosomiasis.

### **2.5.2 The landscape**

The landscape consists of the larger physical structures in the environment. These structures are usually natural, but can be man-made. They include mountains, deserts, rivers, jungle, artificial water reservoirs, and deforested areas. Aspects of the landscape that would influence disease transmission most are the micro-climate, the presence of water, and types of vegetation.

Man-made modifications of the landscape often increase the risk of disease transmission by creating a habitat favourable to vectors or intermediate hosts. Large artificial water reservoirs frequently increase the occurrence of malaria and schistosomiasis <sup>(6)</sup>, for example, and introducing irrigation schemes can increase the occurrence of schistosomiasis <sup>(15)</sup>.

Although the WES specialist working in the field must recognise the risk-factors linked to the landscape, he or she will normally not be able to modify the landscape to reduce the risks of disease transmission.

### **2.5.3 The human surroundings**

Landscape and human surroundings are closely linked, and it is difficult to divide the two clearly. The difference is one of scale; while the landscape normally cannot be modified or improved by individual people, individuals can modify the human surroundings.

Although the landscape will normally be similar for all people living in an area, the human surroundings may be very different for people living in the same region, village, or even household. Many infections are linked to specific circumstances, and people with specific occupations, socio-economic status, gender, or religion may be far more at risk than others. While the father of an African family may be exposed to leptospirosis and plague because he works in sugarcane fields and regularly traps rats, the mother may be exposed to sleeping sickness as she goes to the river to wash clothes, and the children may be exposed to schistosomiasis while playing in the local pond.

The human surroundings are created by a combination of natural elements and how people have modified these elements.

People adapt their surroundings to their needs. If these adaptations are well done, they can help to prevent the transmission of disease. In practice they often

encourage the transmission of disease, however, as people do not have the space, motivation, understanding, time, energy, or financial or material means to do them properly.

In relation to the WES aspects, human surroundings are concerned with water supply, proper handling of excreta, removal of unwanted water, adequate management of solid waste, and control of vectors or intermediate hosts through modification of the environment or change in behaviour.

Waste products like excreta, wastewater, and refuse are disposed of in the human surroundings. These wastes must be properly managed to prevent them becoming a health risk.

The WES specialist working in the field will have to know what aspects of the human surroundings increase the risk of disease transmission. This will enable him or her to determine which aspects play an important role in the transmission of disease in a specific situation. Based on this, an intervention can be planned which will reduce the health risks to the population. More on the health risks relating to the human surroundings, and the components from WES interventions can be found in Chapter 5.

### **2.5.4 Human behaviour**

People behave in a certain way because they believe that they are making the most of their lives. Human behaviour is complex. It is influenced by culture, for example religion, attitudes, and traditional beliefs; by social position, such as gender or age; by availability of means, for example money, energy, time, or material; and by politics.

One type of handpump may be acceptable in one culture, but unacceptable in another. One type of latrine may be preferred by men, while women or children might prefer another. People may not accept things from a government they despise, or from an insulting development worker.

Having access to a safe water supply, or technically adequate sanitation, does not automatically mean people will use them <sup>(25)</sup>. If people do not regard structures as acceptable, appropriate, or as an improvement to their quality of life, they will not be used, or will not be used to their full potential.

Interventions that have only focused on structural improvements have often given poor results in controlling infections. Studies in disease prevention indicate that the most important factor in reducing the transmission of diseases related to WES

is hygiene improvements resulting from changes in behaviour <sup>(13)</sup>. Changing human behaviour in relation to WES should therefore be one of the priorities of the WES specialist.

The specialist will have to identify existing behaviour, attitudes, and behaviour concerning WES and their causes. This will form a base from which health and hygiene promotion can be introduced. All interventions should look at human behaviour, and where needed, reinforce existing positive behaviour while trying to modify behaviour that favours disease transmission.

## 2.6 The future host

The success of a pathogen in infecting a person will depend on:

- the infectious dose of the pathogen, and the number of infectious agents which manage to enter the potential new host (this applies mainly to faecal-oral infections); and
- whether the pathogen can overcome the barriers of the host.

These two factors are now considered in more detail.

### 2.6.1 The infectious dose

The infectious dose is the number of pathogens which have to enter the body of a susceptible person to cause infection. Although this figure should not be seen as exact, it does give an indication of how easily an infection can occur.

The infectious dose is normally only used for faecal-oral infections. As every larva of a helminth can become an adult worm, worms have a very low infectious dose.

Table 2.3 gives the infectious doses of several faecal-oral infections.

Infections with a low infectious dose are more likely to be spread by direct person-to-person contact than infections with a high infectious dose. Measures such as improving drinking-water quality, or reducing the concentration of pathogens in surface water (for example by treating sewage), are more likely to have effect on infections with high infectious doses than on those with low ones <sup>(73)</sup>. Intuitively one would say that flies are more likely to transmit infections with a low infectious dose, but this is complicated by the fact that several bacteria can multiply in food, and thus reach the infectious dose in this way.



**Table 2.3. Examples of infective doses of faecal-oral diseases**

<i>Disease</i>	<i>Infectious dose (in number of pathogens)</i>
Bacillary dysentery (shigellosis) <sup>(16)</sup>	10 to 100
Giardiasis <sup>(16)</sup>	10 to 100
Rotaviral enteritis <sup>(16)</sup>	100 to 10,000
Cholera <sup>(73)</sup>	Usually $10^6$ to $10^8$
Typhoid <sup>(73)</sup>	$10^3$ to $10^9$

### 2.6.2 The barriers of the body against pathogens

The body has a range of mechanisms that prevent a pathogen from causing infection.

The skin and mucous membranes have anti-microbial substances, and the stomach is acid to act as the first barriers against pathogens. Low acidity in the stomach or an open wound (e.g. insect bite, cut, abrasion) can make this barrier ineffective.

The next barriers are mechanisms that react to the pathogen, and try to counter its development. These barriers are not specific to the pathogen, and the body does not need to have been in contact with the pathogen for them to be effective. These mechanisms are the host's resistance against pathogens <sup>(41)</sup>. Resistance is lowered if someone is suffering from other infections <sup>(73)</sup>, or is malnourished, stressed, or fatigued <sup>(41)</sup>. Women have a higher risk of infection when pregnant <sup>(73)</sup>.

An individual's immune system may have experienced a pathogen through an earlier infection or immunisation (vaccination) with inactivated pathogens. When the pathogens enter the person's body, their immune system will recognise the pathogen and make antibodies which will attack the pathogen. This is called active immunity <sup>(45)</sup>. The effectiveness of active immunity depends on the pathogen, and the length of time since the body has been in contact with the pathogen. Active immunity is effective only against that particular pathogen. The effectiveness against bacteria and viruses usually lasts for years <sup>(3)</sup>.

Passive immunity is created by introducing foreign antibodies into the body. An unborn baby receives antibodies from the mother through the placenta, which will protect it for some time after birth. Vaccination with antibodies is another way of creating passive immunity <sup>(73)</sup>. The foreign antibodies will slowly disappear from the body, and passive immunity will usually only last days or months <sup>(3)</sup>.

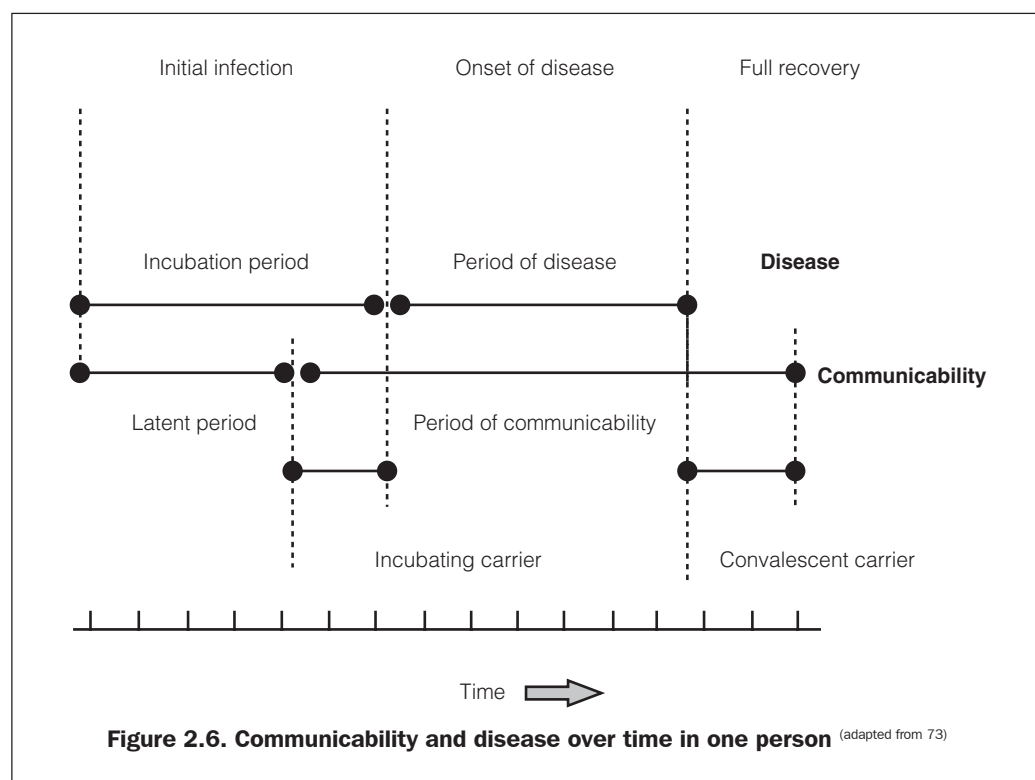
A person or animal who lacks effective barriers (has a poor resistance and/or a low immunity) against a pathogen is susceptible to this infectious agent <sup>(45)</sup>.

Two important practical points define the susceptibility of a population:

- A population that is weakened because of poor nutrition or a high occurrence of disease, fatigue, or stress has an increased risk of disease.
- When a pathogen is very common in a population, or the population is immunised, most people will have some form of immunity against it. In this case the disease will attack mainly children. If the same pathogen is introduced into a population which has low immunity, there is a risk of an outbreak (an epidemic) which can attack all ages.

## 2.6.3 The infection over time

When a pathogen is introduced in sufficient numbers, and overcomes the resistance and immune system of a person or animal, infection will follow. The time between entrance of pathogen and appearance of the first signs of disease or symptoms is called the incubation period. As mentioned earlier, not all infections will result in disease, and for many infections asymptomatic carriers are common.



## DISEASE AND DISEASE TRANSMISSION

The period of communicability is the period in which the host is infectious, or the period in which pathogens are shed in the environment. The time between entrance of pathogen and the onset of communicability is the latent period. This is shown on a timeline in Figure 2.6.

In some infections the period of communicability starts before illness is apparent. Hosts who can transmit the pathogen before showing symptoms are called incubating carriers. If the period of communicability extends beyond the end of the illness, the hosts are called convalescent carriers.

## Chapter 3

### **Disease in the population**

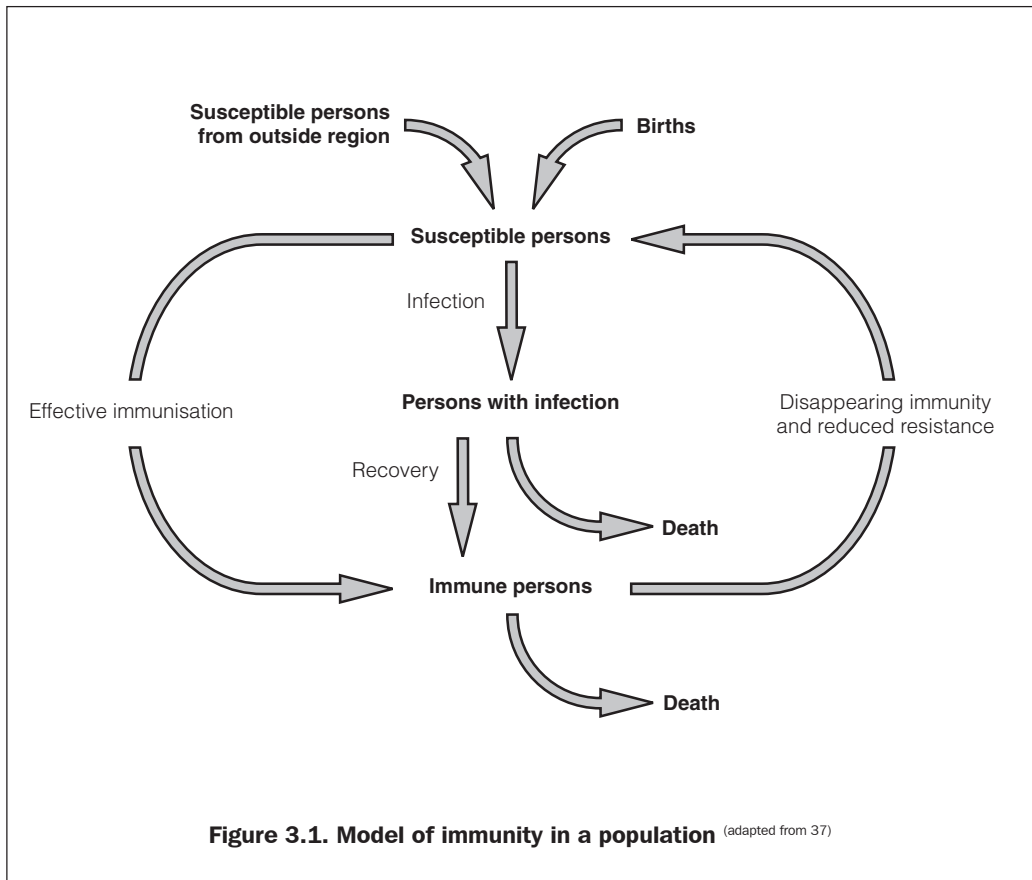
This chapter introduces the dynamics of communicable disease in a population. We look at immunity, endemic and epidemic occurrence of disease, some epidemiological concepts, and we consider mortality and morbidity rates in a population in both stable and emergency situations.

#### **Immunity in the population**

Immunity plays a crucial role in the dynamics of disease transmission. The more people are immune, the less likely it is that a pathogen will find a susceptible person. If enough people are immune, the chance of the pathogen causing an infection becomes so small that transmission stops, even though there are still susceptible people. This is called herd immunity <sup>(41)</sup>. With poliomyelitis, for example, if 80 to 85 per cent of the entire population is immune, the virus will disappear <sup>(50)</sup>. A population can lose its herd immunity through births, migration of susceptible people into the population, or waning immunity in the population over time. Figure 3.1 presents a model of immunity in the population.

Two important points can be deduced from Figure 3.1:

- The immunity in a population is the result of people either overcoming the infection or being immunised (vaccinated).
- The susceptibility of the population in an area increases through the influx of non-immune people, birth, and from people losing their immunity (through time or another reason, such as HIV infection).



## 3.1 Endemic and epidemic occurrence of disease

The occurrence of an infection in a population is determined by many factors, including the pathogen, its persistence and/or latency, whether it has a high or low infectious dose, whether it can multiply outside the host, and whether it infects both humans and animals or only humans. It depends on hosts, how many pathogens they shed, and whether their behaviour favours transmission. It depends on the environment in which transmission occurs, its climate, and its human physical environment, which may favour direct transmission, vectors, or intermediate hosts. It depends on potential new hosts and their behaviour, resistance, and immunity against the infection. (These factors were covered in Chapter 2.)

These factors can either favour, or oppose, the transmission of the pathogen from a host to a potential new host. Favouring and opposing factors balance each other. Three situations are possible:

- The opposing factors are stronger than the favouring factors: the infection disappears or does not occur. This situation is what we try to achieve.
- The opposing and favouring factors are in balance: there is a continuous presence and transmission of the infection in the population. The disease is endemic.
- The opposing factors are weaker than those that favour transmission: the occurrence of the infection increases in the population. If the occurrence is clearly more than normally expected, then the infection is epidemic.

This balancing between the opposing and favouring factors is a dynamic process that can easily alter with changes in the pathogen, hosts, environment, or potential new hosts.

Communicable diseases are usually either absent, endemic, or epidemic in a population (although sporadic or imported cases can occur). Most infections can be both endemic and epidemic, but only some can cause explosive, severe epidemics. Even though epidemics can be dramatic, endemic disease is often worse for the population <sup>(51)</sup>.

In health programmes it is the eradication of frequent, severe, and preventable or controllable infections that should receive priority <sup>(71)</sup>.

### **3.1.1 Endemic occurrence of disease**

An infection is endemic when it is always present in a population <sup>(3)</sup>. How often the infection occurs depends on the factors mentioned in Section 3.1, but seasonal fluctuations of infections are also common.

When an infection is common and results in long-lasting immunity, disease will usually occur in childhood, as adults will have built up immunity. If the infection is highly endemic, it is unlikely that an epidemic will occur, unless several subtypes of pathogens can cause the same disease and the population is immune against only one of these, which can happen with dengue fever, for example <sup>(3)</sup>.

Disease is often unevenly distributed in a population. Depending on people's occupation, environment, and behaviour, some may be more exposed to pathogens than others. Children may be more at risk because of their behaviour (e.g. schistosomiasis caused by playing in water) <sup>(16)</sup>; the poor may be more at risk

because of the conditions in which they live (e.g. poor housing resulting in Chagas disease <sup>(73)</sup>); people with certain occupations or living in specific locations may be more exposed (e.g. farmers or sewage workers would come in contact more easily with leptospirosis). It is important to identify the people who are most at risk, and why to know who to target and what preventive measures to take.

### 3.1.2 Epidemic occurrence of disease

An epidemic, or outbreak, occurs if there are clearly more cases of an infection than would be expected in a given area over a given period of time or season <sup>(71)</sup>.

Outbreaks can occur if the following features are combined <sup>(10)</sup>:

- a pathogen must be introduced or be present in the area;
- the environment must be favourable to transmission; and
- there must be enough susceptible people in the population.

There is a large risk of an outbreak when:

- infected people enter a non-immune population, in an environment favourable to transmission (e.g. infected refugees or migrants enter a non-endemic area);
- susceptible people move into an endemic area (e.g. non-immune refugees or migrants enter an endemic area; people enter an area where a zoonosis occurs in an animal population <sup>(79)</sup>);
- the population has lost its resistance or immunity, and the pathogen is reintroduced (e.g. people's immunity has diminished over time; babies have been born; or people are suffering from disease or malnutrition <sup>(73)</sup>); and
- the environment has changed, and has become more favourable to transmission (e.g. construction of a dam has produced an environment favourable to mosquitoes (a malaria vector) or snails (the intermediate host of schistosomiasis)).

An outbreak can become an emergency if the infection is severe, if the society is disrupted because of the number of cases occurring, or if medical infrastructure is unable to cope because of lack of personnel, material, or organisational skills <sup>(10)</sup>.

The most severe epidemics are those caused by infections which are easily transmitted, have short incubation periods <sup>(71)</sup>, and have a potentially severe outcome. The main infections that cause severe outbreaks are diarrhoeal diseases (e.g. cholera, bacillary dysentery), yellow fever, malaria, epidemic louse-borne typhus fever, and louse-borne relapsing fever, but other infections can cause emergencies too.

## CONTROLLING AND PREVENTING DISEASE

Most of the infections covered in this manual can cause epidemics which impact hard on society or individuals. They will not normally cause emergencies though, as they develop slowly, are less serious, or people have high levels of immunity. Where an infection is endemic it is impossible to give a threshold level that marks the beginning of an epidemic, as this depends on what is ‘normal’ in a given population, in that area, in that season. Where cholera is not endemic, one case of locally acquired cholera will be declared an epidemic <sup>(10)</sup>. Where cholera is endemic, two new cases in a week would not necessarily cause concern. An epidemic would be confirmed if more cases occur than occurred in the same season in the recent past <sup>(55)</sup>. Table 3.1 presents the epidemic threshold level for several diseases.

As with endemic occurrence of disease, outbreaks may be limited to specific groups of the population. Analysis of outbreaks are covered in the next section.

**Table 3.1. Threshold levels of epidemics <sup>(10)</sup>**

<b><i>Infection</i></b>	<b><i>In a non-endemic population</i></b>	<b><i>In an endemic population</i></b>
Salmonellosis	A group of cases with one common source of infection.	
Cholera	One locally infected confirmed case <sup>(a)</sup>	A ‘significant’ increase over what is normal in that season
Yellow fever	One confirmed case in a non-immune population with a presence of vectors	A ‘significant’ increase in the number of cases over a ‘limited time’
Mosquito-borne arboviral encephalitis	A group of cases in a non-immune population (the first case is a warning)	A ‘significant’ increase in the number of cases caused by that specific pathogen over a ‘limited time’
Malaria	A group of cases occurring in a specific area	Rare
Plague	One confirmed case	A cluster of cases caused by domestic rodents or respiratory transmission or an epidemic in rodents
Epidemic louse-borne typhus fever	One confirmed case in a louse-infested, non-immune population	A ‘significant’ increase in the number of cases over a ‘limited time’

<sup>(a)</sup> A ‘confirmed case’ is an infection confirmed by laboratory tests.



## 3.2 Introduction to epidemiology

Epidemiology is the study of the distribution, occurrence, and causes of a disease in a population to improve the existing health situation <sup>(54)</sup>. Epidemiology covers endemic as well as epidemic occurrence of disease, and the approach taken to both is similar.

A full epidemiological study will consist of four phases <sup>(71)</sup>:

1. An assessment of the distribution and frequency of a disease in a population.
2. Determining and analysing the causes of the disease.
3. Conducting an intervention to try to reduce the occurrence of the infection.
4. Evaluating the effectiveness of the intervention.

Conducting a full and methodical epidemiological inquiry is complex, and should remain the domain of an epidemiologist, but an intuitive form of epidemiology is already used by WES specialists. Identifying poor personal hygiene, caused by lack of water, as a cause of trachoma or diarrhoea, and installing a water supply to improve water availability, is intuitive epidemiology. Although intuitive epidemiology does not have the scientific rigour of classic epidemiology, it is more practical for fieldworkers.

The following sections will help water and sanitation specialists to take this intuitive approach to disease prevention.

### 3.2.1 Data collection

Epidemiology is about information. The mortality and morbidity rates of those diseases which are an important health problem will have to be collected from local medical staff or authorities, or from medical agencies working in the area. The rates may not be very accurate, but for a WES specialist accuracy is not essential. Collect the monthly or weekly incidence rates of diseases related to WES, going back for some years if possible (i.e. the number of new cases occurring in a population per unit of time <sup>(3)</sup>).

The incidence rates, combined with a questionnaire or survey on the background and the environment of the cases, should answer the following questions:

- What infection is being investigated?
- Who is affected? What are their characteristics: socio-economic background (e.g. income level), occupation (e.g. agricultural workers), age, sex, ethnic group, specific behaviour (e.g. use of one specific source of water) or other characteristic (e.g. HIV infected)?

- Where does the disease occur (place of exposure)? What is the geographical distribution (e.g. altitude) and the environment (e.g. slums, swamps, forests, poor sanitation).
- When does the disease occur? Is there a season (e.g. wet season, when many vectors are present), a specific occasion (e.g. one week after a feast, or visit to a town, or a strong increase of the disease in years after the construction of a dam) <sup>(71)</sup>?

Being aware of the risk factors which can cause transmission will help to identify relevant information. More detailed information about risk factors concerning WES can be found in Chapter 5.

The local risk factors that cause transmission will have to be identified by surveying the environment and human behaviour. It is also important to look at local attitudes and beliefs regarding the disease and its prevention, as these could affect potential interventions. The survey will also have to assess the risk the infection poses, and the capacity of the local authorities to deal with the existing situation or with a potential outbreak. Then the relative importance of the different risk factors will have to be determined.

While endemic occurrence will usually exist in a relatively static situation, an epidemic is always the result of some kind of change which favours transmission. Either a pathogen is introduced into a susceptible population, the population has become more susceptible, or the environment has changed in a way which favours transmission. This change should be identified.

In an outbreak, the primary transmission, or the way the initial cases are infected, may be different from the secondary transmission, or the way the pathogens are transferred from the initial cases to new cases <sup>(8)</sup>. An outbreak of typhoid fever may originate with infected drinking-water, while secondary transmission may occur through infected food handlers. Similarly, with endemic diseases not all cases need to be infected in the same way.

Once the local risk factors are identified and their importance assessed, the potential effects of eliminating or controlling these factors has to be estimated. By combining this information with what is known about local limitations and resources, it is possible to come up with an indication of what type of intervention would be appropriate in a particular place. When an outbreak results in an emergency, all feasible measures that could potentially reduce transmission should be taken.

This analysis will usually be enough to choose an intervention for endemic and epidemic diseases. Trying to analyse an outbreak can be more complex, as the process is more dynamic. The following aids can help analyse an outbreak.

### **3.2.2 Aids in analysing an outbreak**

The minimum requirement to follow and analyse an outbreak is up-to-date information. A sufficient number of competent and motivated medical staff must be present to identify cases, and reliable and regular reports on cases must be collected at a central point.

It is usually qualified medical personnel who will analyse an outbreak, but the WES specialist has to understand some of the basic aids that can be used, with a questionnaire or survey, to assess the risks and extent of the outbreak, and the possible sources of the epidemic.

#### **3.2.2.1 *The spot map: mapping the outbreak***

A ‘spot map’ is a map on which the location of the cases is marked. The spot map shows both the distribution and trend of the outbreak, and potential sources of infection <sup>(55)</sup>. It also indicates which villages or neighbourhoods are most at risk of further transmission. If possible, the map should show where people became infected to help locate the source of infection. If the infection is easily spread from person to person, it may be useful to map where the cases live or work to predict where there is the greatest risk of secondary transmission.

#### **3.2.2.2 *The epidemic incidence curve: following the outbreak in time***

During an outbreak an ‘epidemic incidence curve’ should be drawn. It is a graph that plots the number of new cases day by day, or week by week. The curve can then be extrapolated to show when the initial infection occurred. Looking at the whereabouts and activities of the initial cases will help to pinpoint the cause of the infection.

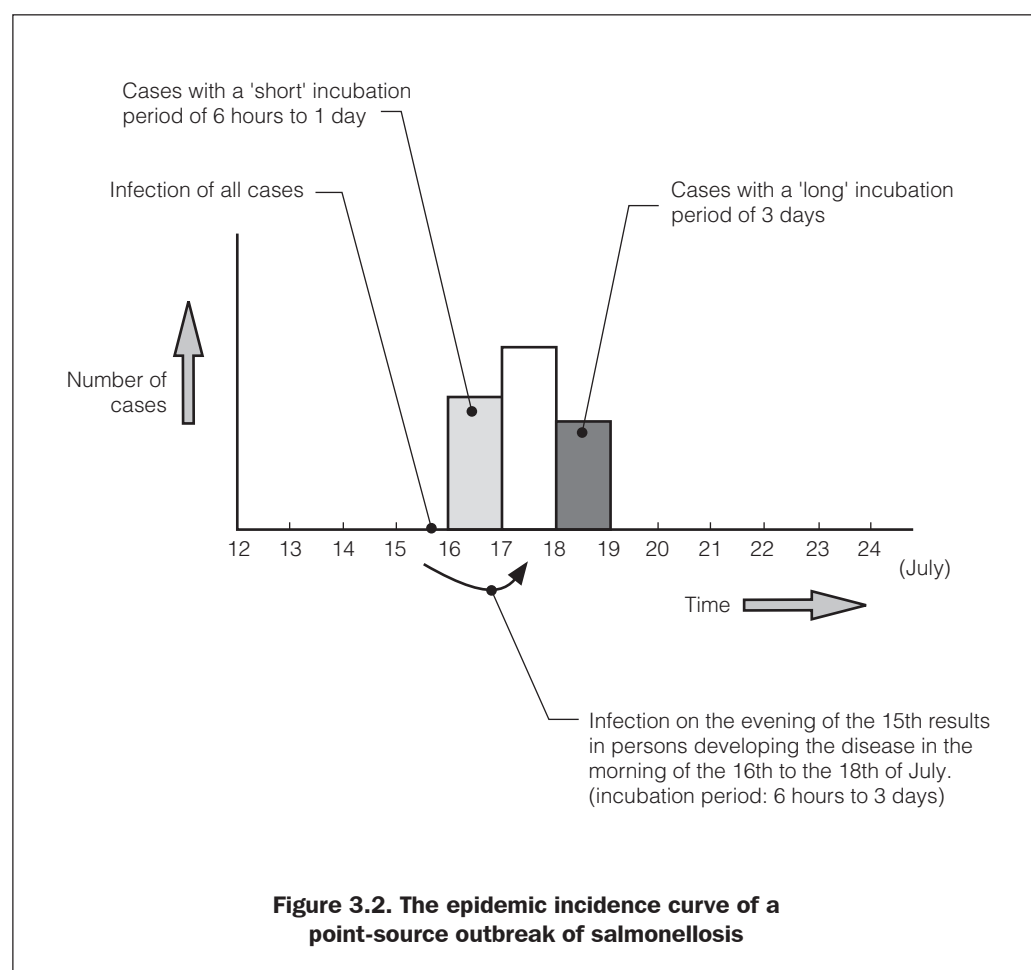
The curve can highlight a trend and the nature of the outbreak <sup>(71)</sup>.

### **The point-source or common-source outbreak**

A point-source outbreak is caused by a particular incident that infects a group of people almost simultaneously. It is typical of water-borne and food-borne outbreaks, or outbreaks caused by handling infected material <sup>(55)</sup>. This type of outbreak could be caused by contaminated food served at a feast, for example, or travellers drinking from a contaminated stream. By plotting the incidence curve of an outbreak of a known disease, the approximate time of primary infection can be determined. The first cases that appear are the ones with the shortest incubation

period; the last ones are those with the maximum incubation period. Going back in time for the length of the incubation period indicates when infection occurred. By looking at where the people were and what they were doing at that time, the source of infection can be identified <sup>(73)</sup>.

Figure 3.2 shows a point-source outbreak of diarrhoea in a village. The first cases of diarrhoea appear on the morning of 16 July. The diarrhoea is identified as salmonellosis. As the incubation period of salmonellosis is between six hours and three days <sup>(3)</sup>, people were probably infected on the evening of 15 July. A survey shows that on the evening of the 15th all the known cases attended a funeral. At this funeral food was served, and the majority of those who ate meat have fallen ill, while those who did not have no problems. In this case it is probable that the meat served at the funeral was the source of infection.

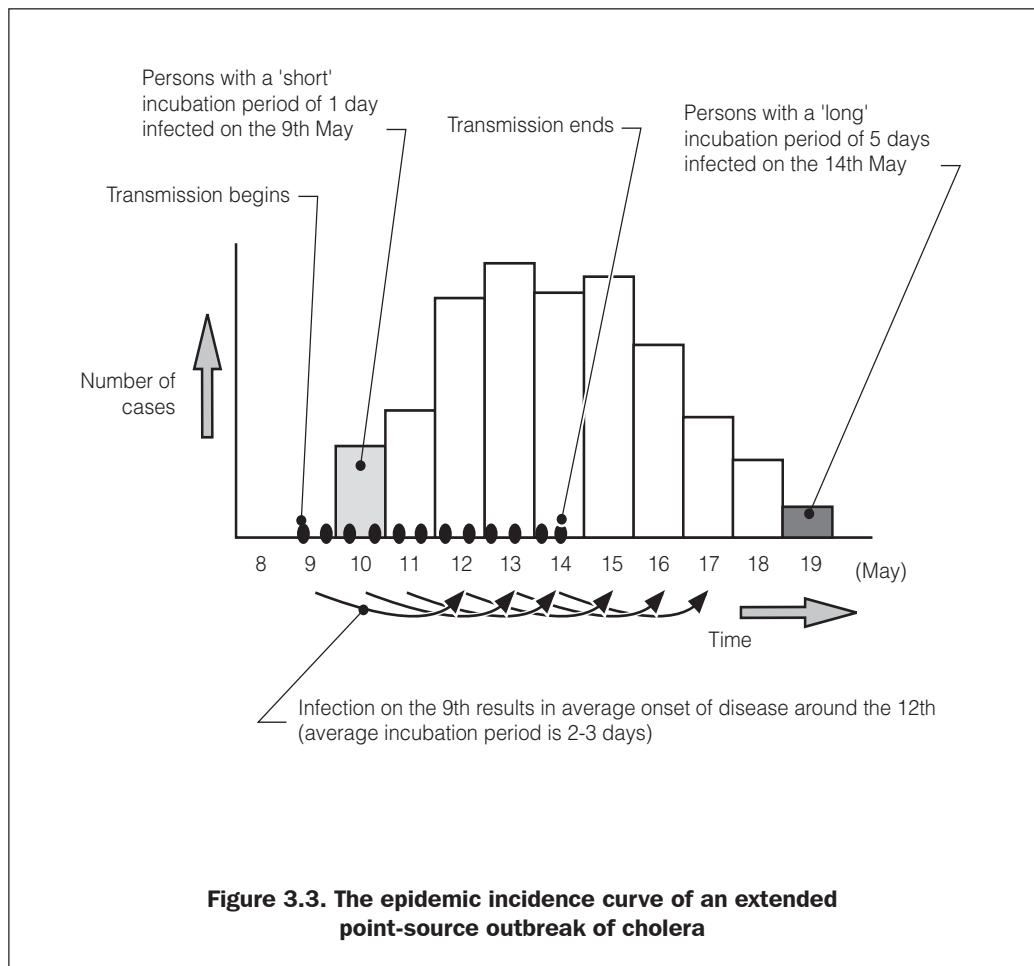


### The extended point-source outbreak

These outbreaks are caused by specific sources that have infected people over a period of time. The onset is comparable to a point-source outbreak, but cases continue to appear over a longer period <sup>(71)</sup>. This type of outbreak could be caused by sewage leaking into a water supply system, for example.

The process of finding the source of infection is similar to that with the point-source outbreak. The probable time of initial infection is determined by going back to the time the first cases appear and back further for the shortest incubation period of that infection. A survey of where the first cases occurred, and what those people were doing will normally indicate the probable cause of infection <sup>(73)</sup>.

Figure 3.3 shows the epidemic incidence curve of an extended point-source outbreak of cholera. As the shortest possible incubation period of cholera is one



day, the initial infection probably occurred on 9 May. A survey shows that all the cases ate at a particular food stall on the local market. The stall was closed the evening of the 14th. Cases continued to appear until the 19 May because some of the people infected on the 14th will have had an incubation period of five days.

## **The propagated-source outbreak**

This type of outbreak is the result of progressive transmission. One case, the primary case, will infect a cluster of cases, the secondary cases, who will infect the next cluster, the tertiary cases, and so on. Usually the onset and decline of the outbreak will be more gradual than a point-source outbreak. This type of outbreak is possible with most infections covered in this manual.

Every cluster of cases will show a peak in the incidence curve. The period between the peaks is called the 'serial interval' <sup>(73)</sup>. The serial interval will depend on the latent period, the period of communicability of the host, and the time it takes for the pathogen to develop in a vector or intermediate host. This will often be about the average incubation period, plus, if applicable, the period of development in the vector or intermediate host. The longer the latent period, the longer the period of communicability, and the longer the time the pathogen needs to develop in the vector or intermediate host, the more spread out over time the curves will be.

The number of cases that will occur will depend on how effective transmission is. The presence of risk factors such as overcrowding, behaviour which favours transmission, a large susceptible population, or an environment favourable to vectors or intermediate hosts, will increase the number of cases <sup>(55,71)</sup>.

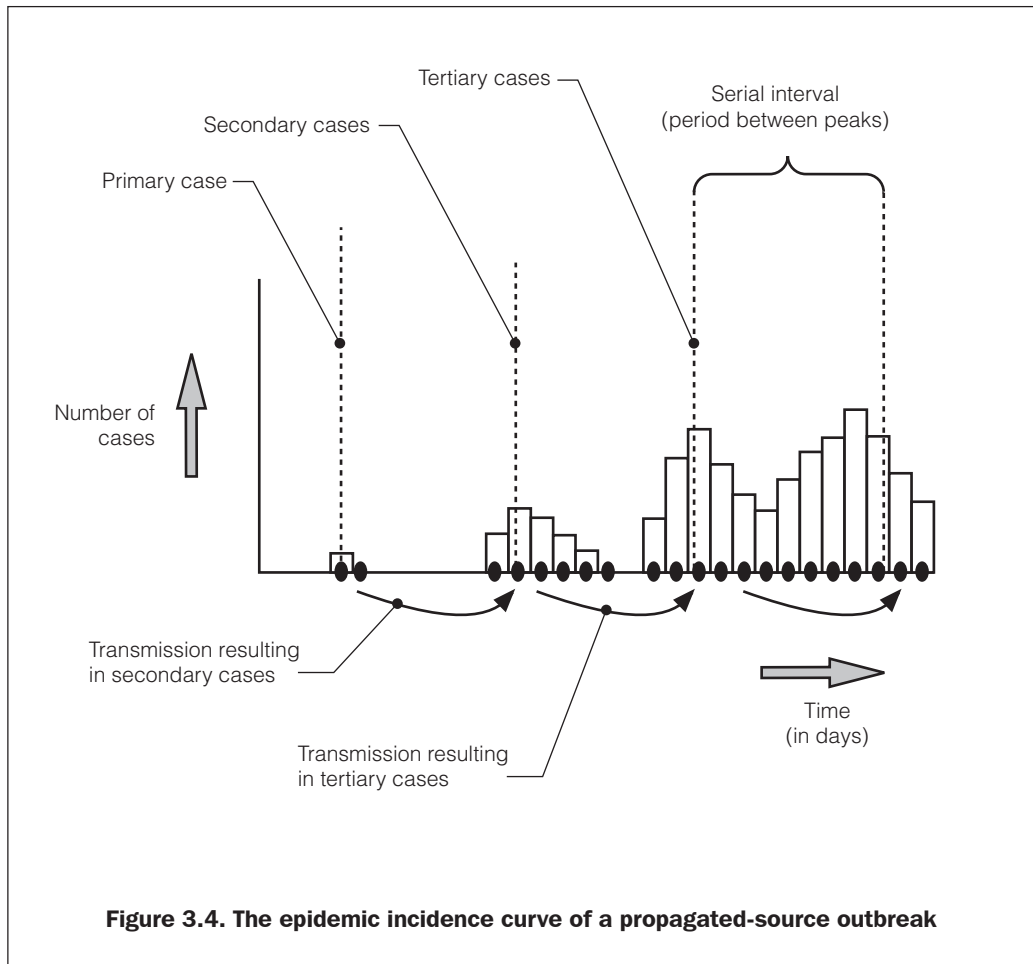
Figure 3.4 is an example of a propagated-source outbreak. This is a theoretical example of an infection that has an incubation period of seven to 10 days and period of communicability of two days.

### **3.2.2.3 Limitations of the spot map and the epidemic incidence curves**

The spot map and epidemic incidence curves have several limitations:

- The reported rates always lag at least one incubation period behind the actual situation of the infection. The cases identified now were infected one incubation period earlier. People infected since then are developing the infection, but do not show any symptoms yet (even if transmission were to stop abruptly, new cases would continue to appear for the length of the incubation period). Delay is also likely because of communication problems between the field and the central registration point.

## DISEASE IN THE POPULATION



**Figure 3.4. The epidemic incidence curve of a propagated-source outbreak**

- Reliable and up-to-date information identifying the infection and recording cases is vital. Problems in identifying or reporting cases make analysing an outbreak difficult.
- Normally only symptomatic cases will be registered, and asymptomatic infections will not be identified. This means that you may only be seeing the tip of the iceberg.
- The epidemic incidence curves only indicate when the initial infection probably occurred. The actual cause of the outbreak must be identified by people in the field assessing the cases and their environment.
- When cases infected by primary transmission spread the pathogen to others, they may do so through a different route than the one that infected them. With secondary transmission every new case becomes a potential new source of infection for others, behaving as little (extended) point-source outbreaks them-

selves. The incidence curve may be the result of an accumulation of these many little outbreaks. Cases can often transmit the infection over long periods of time, which will ‘smear out’ the distinct peaks in a propagated-source outbreak, so the epidemic incidence curves found in practise will not rarely look like the neat models shown here.

### 3.3 Mortality and morbidity rates in a population

The mortality and morbidity rates of infections are an indication of health problems in a population. Combined with an environmental assessment, the rates of important infections will help to identify health risks relating to WES. The importance of a disease will depend on:

- its frequency in the population (i.e how common it is, or how big is the risk of an epidemic); and
- its severity ( i.e. whether the infection causes disability or death) <sup>(71)</sup>;

Seasonal rates are important in identifying seasonal health risks and potential epidemics.

#### 3.3.1 Mortality rates in a stable population

Table 3.2 presents the Crude Mortality Rate (CMR) and the Infant Mortality Rate (IMR) common to a stable population. The CMR is the total number of deaths in the population due to disease, injury, and malnutrition. The IMR is the total number of deaths in children under the age of one year per total births.

The figures for poor communities are not threshold levels, but give an idea of what to expect. The rates for these communities are not acceptable at these levels, and should be brought down, preferably to the CMR of developed communities.

**Table 3.2. Mortality rates in a stable population**

	<i><b>Situation</b></i>	<i><b>Mortality rates</b></i>
<b>Crude Mortality Rate (CMR)</b>	Developed communities	10 deaths/1,000/year <sup>(71)</sup> (0.3 deaths/10,000/day)
	Poor communities	18-25 deaths/1,000/year <sup>(11,47)</sup> (± 0.6 deaths/10,000/day)
<b>Infant Mortality Rate (IMR)</b>	Poor communities	60-150 inf.deaths/1,000births/year <sup>(71)</sup> (± 3 deaths/10,000/day)



It is not possible to give ‘acceptable’ incidence rates for specific diseases in a population, as this will depend heavily on the local situation, but the figures should be lower than the ones presented in Table 3.4. In practise the rates will have to be compared with the feasibility of reducing morbidity by improving the situation through an intervention.

### 3.3.2 Mortality and morbidity rates in emergency situations

In an emergency situation the CMR is the most practical indicator of the health status of a population. As long as the CMR in a population is more than 1 death/10,000/day the situation remains an emergency <sup>(47)</sup>. Mortality rates in the initial phases of an emergency can be much higher than this <sup>(11,47)</sup>. Table 3.3 presents figures of what would be acceptable upper threshold levels in the post-emergency phase in camps for displaced people or refugees.

<b>Table 3.3. Threshold levels of Crude Mortality Rate and Infant Mortality Rate in camps</b>	
	<b><i>Mortality rates</i></b>
<b>Crude Mortality Rate</b>	1 death/10,000/day
<b>Infant Mortality Rate</b>	± 2.5 deaths/10,000/day

Even though it is difficult to give concrete figures on incidence rates of diseases, Table 3.4 gives an indication of acceptable rates in camps for displaced people or refugees.

<b>Table 3.4. Indicative acceptable incidence rates and specific mortality rates in camps for displaced persons or refugees <sup>(72)</sup></b>		
	<b><i>Incidence rate</i></b> <i>(in cases/10,000/week)</i>	<b><i>Mortality rate</i></b> <i>(in deaths/10,000/week)</i>
<b>Diarrhoea total</b>	60	
Acute watery diarrhoea	50	1
Bloody diarrhoea	20	
Cholera	Every suspected case must be reacted upon	
Fever of unknown origin	100	0.5
Malaria	20	
Skin infections	40	-
Eye infections	35	-

Children under five are more likely to develop disease, and incidence rates of roughly 1½ times those presented here would be acceptable in this group <sup>(72)</sup>.

## Chapter 4

### **Water and environmental sanitation projects**

This chapter looks at the problems that WES projects try to address. The planning of WES interventions is considered briefly, and the project cycle is presented. Issues which will have to be considered to improve the impact and sustainability of projects are discussed, and the chapter concludes with a more global perspective of development by looking at poverty in society.

Some terms used in this chapter:

**NGO:** non-governmental organisation

**Agency:** any organisation that is implementing a project, including both national and international NGOs

**Project:** an intervention that tries to achieve one specific objective (e.g. to provide an adequate and sustainable water supply for 20,000 people living in particular villages) through specific activities (e.g. installing 60 handpumps)

**Programme:** is usually on a larger scale than a project, and has a goal which is more general (e.g. a sustained improvement of health for 40,000 people living in low-cost housing areas in Jakarta). A programme will usually have several objectives (e.g. install adequate and sustainable services for water supplies, sanitary services, hygiene promotion, and solid waste management), and is usually made up of several projects <sup>(adapted from 19,20,23)</sup>.

Although this manual only covers infections linked to WES, it should be remembered that these are only part of the total health burden of people in developing countries.

## 4.1 The price of poor WES

Infectious diseases related to WES are very common in developing countries. It is estimated that 1 billion people are infected with roundworm <sup>(44)</sup> and the same number with hookworm <sup>(4)</sup>. A study in Lubumbashi, in the Democratic Republic of Congo, showed that more than 90 per cent of young children in poor areas were infected with malaria and/or worms <sup>(63)</sup>. Estimates in the 1980s of the number of infections that occurred worldwide in one year were: diarrhoea, up to 5 billion; malaria, around 150,000,000; trachoma, around 25,000,000 <sup>(59)</sup>.

Every year an estimated 2,900,000 people die of diarrhoea <sup>(52)</sup>, around 900,000 of malaria <sup>(76)</sup>, and around 600,000 of typhoid fever <sup>(3)</sup>. Every year these three diseases together kill the equivalent of the population of Norway – more than 12,000 deaths per day.

Illness more often results in (temporary) disability than in death. Infections like leprosy, trachoma or filariasis are rarely fatal, but often result in permanent disfigurement, blindness, and disability <sup>(59)</sup>. DALYs (Disability-Adjusted Life Years) are a measure of the cost of disease. DALYs represent the number of years lost due to early death, and time and severity of the disability caused by the disease. Table 4.1 shows the number of DALYs lost to several important infections every year.

The developing world is paying the highest price for disease. Only 12 per cent of the suffering caused by disability and early death occurs in developed countries. In developing countries, 35 per cent of all DALYs lost are a result of communicable disease, compared to just over 4 per cent in developed countries <sup>(51)</sup>.

**Table 4.1. DALYs lost to disease worldwide, yearly figures** (from 51 and 76)

<i>Infection</i>	<i>DALYs</i>
Diarrhoeal disease	99,600,000
Malaria	31,700,000
Roundworm infection	10,500,000
Trichuriasis	6,300,000
Schistosomiasis	4,500,000
Trachoma	3,300,000
Chagas disease	2,700,000
Leishmaniasis	2,100,000
Sleeping sickness	1,800,000
Hookworm disease	1,100,000

Disease is expensive at all levels. At a personal level illness results in suffering, loss of time and money because of disability, payment for medical care, transport to health facilities, care by a healthy person, and the need for special food. At national level disease costs because medical facilities have to be maintained, care and medication must be provided, and because part of the workforce is unable to produce.

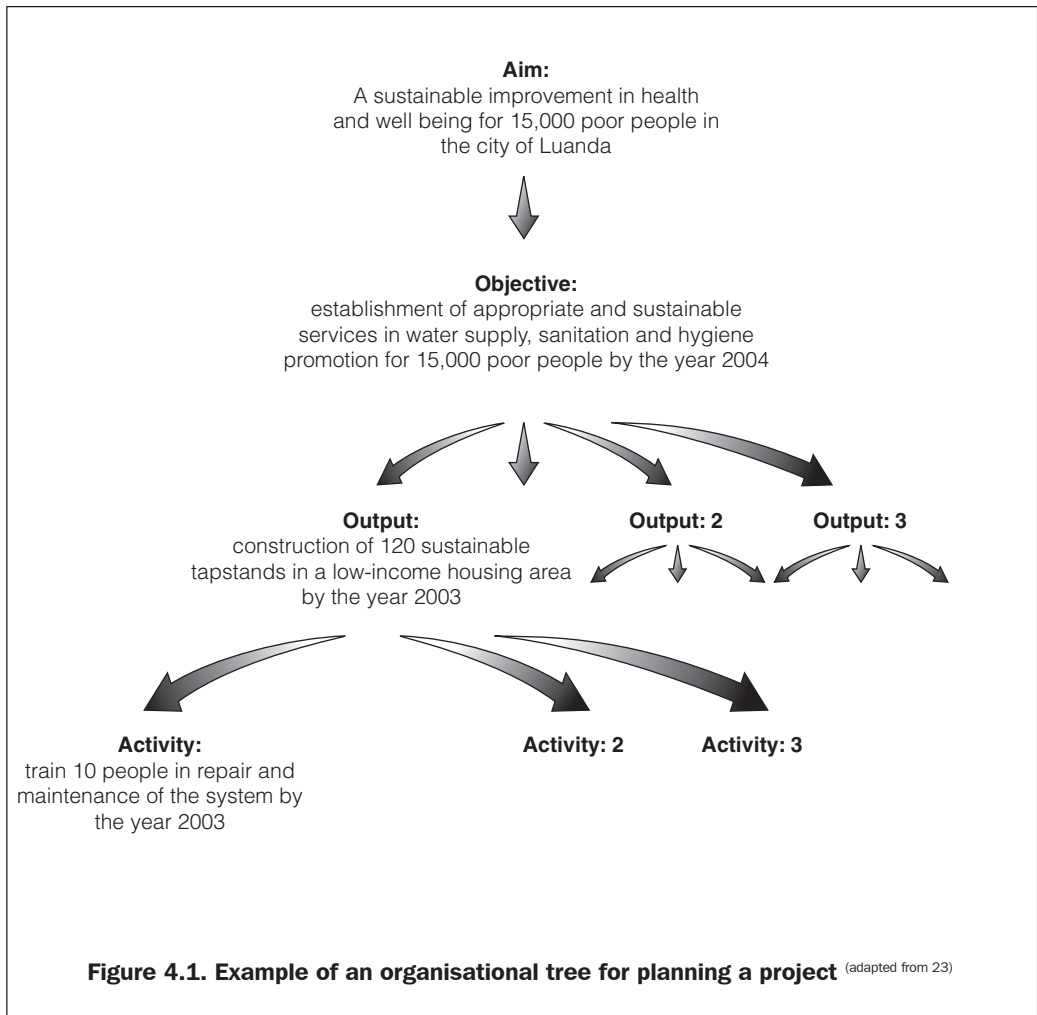
Poor health is not the only price people pay for poor water supply and (environmental) sanitation. Often water has to be carried over long distances, taking up energy and time. In some regions over half the daily energy available to one person is needed to carry the water used by the household every day <sup>(1)</sup>. This time and energy cannot be invested in other activities like going to school, or growing vegetables for sale or consumption. Carrying heavy loads of water can result in deformities of the body and other physical problems <sup>(20,38)</sup>. Where water must be bought from vendors, it may account for a large proportion of the household's expenditure (up to 40 per cent of the income of a household is mentioned) <sup>(69)</sup>. Where (environmental) sanitation is poor, people may live or work in an unpleasant environment of bad smells, nuisance by insects or rats (which can carry disease), and unsightly conditions.

### **4.2 The planning of WES projects and the project cycle**

The aim of WES projects and programmes is usually to improve the health and socio-economic conditions of a population <sup>(20)</sup>. Health is improved by breaking the transmission cycle of diseases present in the project area. People's socio-economic conditions are improved by helping people to gain time, energy, money, and skills in management and decision-making.

Projects and programmes are best approached in a methodical manner. This ensures that no steps are overlooked in the planning and implementation of the project. Although we will not go into much detail on how to plan and conduct projects or programmes, we will point out some important issues.

To be able to assess whether a project functions well, or has been successful, every project should have a clear goal, and a clear idea of how this goal is going to be achieved. Figure 4.1 shows how an organisational tree could be set up for a project. The objective must lead to the aim; to attain the objective, certain outputs will have to be achieved; and to realise the outputs, certain activities will have to be accomplished. In the end everything that will have to be done and achieved in the project must be included in clear and measurable form in the organisational tree, which is a simplified form of the logical framework.

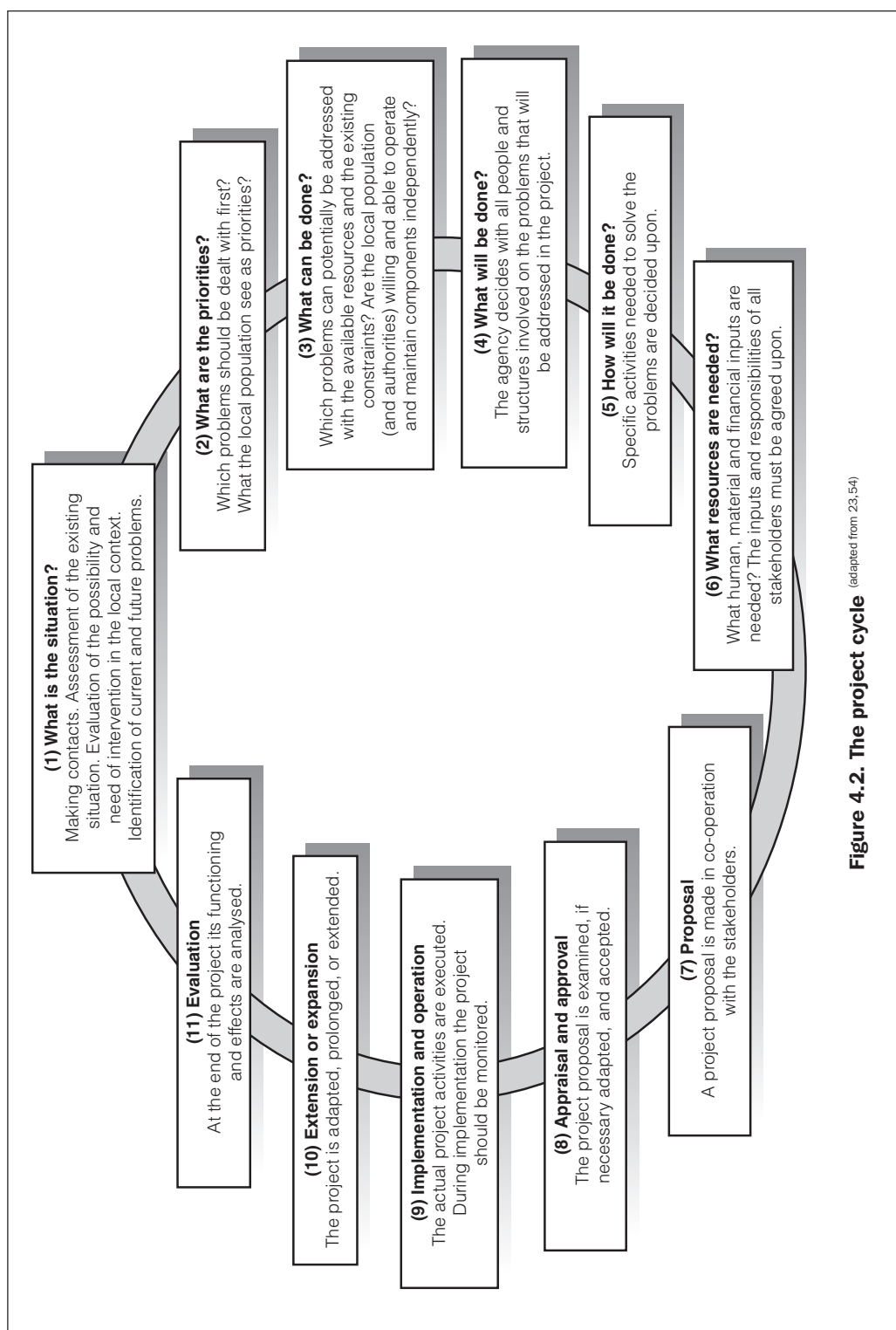


A project goes through a cycle, the project cycle, which consists of a sequence of assessment, planning, implementation and evaluation activities.

Figure 4.2 presents the steps of project cycle.

## 4.3 Improving impact and sustainability

Projects take place in a dynamic society with its own cultural, financial, physical/technical, and institutional/political particularities. It is therefore difficult to predict all the short- and long-term effects of an intervention. Although it is impossible to eliminate all uncertainties, a thorough assessment of the local situation, and an intervention that is well adapted to the local situation, will improve the chances of success of a project.



**Figure 4.2. The project cycle** (adapted from 23, 54)

This section looks at some of the cross-cutting issues which must be addressed in the project planning phase to improve impact and sustainability.

### **Integral approach to projects and programmes**

Most of the infections covered in this manual could be controlled by any one or several components of WES. Water supply, sanitation, drainage, solid waste management, and vector control should therefore always be combined to achieve the best overall results in disease control. Interventions that combine the different components are usually the most effective in improving the health situation <sup>(38)</sup>.

Health is affected by many factors other than WES. Programmes should try to combine components of all relevant sectors (e.g. WES, medical, environmental, economic) to achieve maximum impact. Programmes are most effective when projects from different sectors are integrated <sup>(26,38)</sup>.

### **Hygiene behaviour and health and hygiene promotion**

Adequate hygiene behaviour is crucial in preventing disease. Improving infrastructure without improving behaviour will rarely result in effective disease control. The largest improvements in health have occurred where hygiene improved because of a change in behaviour <sup>(13)</sup>. Improving hygiene behaviour through health and hygiene promotion should therefore receive the same priority as structural improvements.

Changing people's behaviour is difficult and often requires prolonged education. Health and hygiene promotion must therefore be included in a project from the beginning, and will require its own time scale, material, and people with specific skills <sup>(20)</sup>. Health and hygiene promotion must be adapted to the local culture <sup>(27)</sup>.

### **Technical aspects**

Infrastructure must be designed to fulfil needs. Where the population density is high and the infiltration capacity of the soil low, a sewage system may be appropriate. In most other cases, however, sewerage will be inappropriate because it is expensive and requires demanding operation and maintenance.

Often different components of WES need to be supplied together. A water supply system should always be combined with adequate wastewater disposal; a sewage system needs a reliable piped water supply system.

Infrastructure should be adapted to local needs and capabilities. A handpump may be very convenient, but a proper hand-dug well may be more appropriate in terms of local capacity to build and maintain the structure. A brick latrine may look

good, but may also be too expensive for local people. If people use corncobs to clean after defecating, a pour-flush latrine will soon be blocked.

Changes in population, or in use of the structures, have to be planned for. The number of people using the infrastructure may increase because of natural growth or migration. A latrine designed to receive only excreta may not cope with the sullage if a piped water supply is later installed. Where possible, infrastructure should be built with potential upgrading or extension in mind.

### **Operation and maintenance**

Operation and maintenance (O&M) must be addressed early in the project. Infrastructure which functions poorly often becomes a health threat, and improvements will only last if a reliable O&M system is in place. O&M must be as easy and affordable as possible. Spare parts and other necessary materials must be affordable and easy to obtain, and responsibility for O&M should be agreed upon early in the planning of a project.

Infrastructure should be installed at family level if possible, as O&M by users is the most reliable system. To facilitate this, local construction techniques and materials should be used as much as possible. People should be offered training and adequate tools for building and O&M. The quality of construction should be as high as possible, but adapted to what is adequate and affordable to the users.

### **Socio-cultural aspects**

Even if the population understands the importance of improved infrastructure and behaviour, there is no guarantee that the infrastructure will be used or good behaviour practised<sup>(18)</sup>. If users believe the components are inadequate, they will not respect them.

Although an outsider will never completely understand people's perceptions of adequate and inadequate, it is important to understand the issues that are relevant to the project. For this the traditional beliefs, ideas, and expectations of the people about WES must be identified and taken into account.

Societies are not homogeneous; they are made up of people of different sex, age, religion, ethnic origin, socio-economic status, occupation, and caste. Some are more vulnerable than others, particularly women, children, religious and ethnic minorities, and people who are old, disabled, or poor. These groups of people must be identified and included in the project as much as possible. As domestic WES is often the responsibility of women, they should play an important role in the planning of an intervention<sup>(23)</sup>. All components must be acceptable to all users.



If certain groups do not see the infrastructure as adequate, they will either not use it or use it incorrectly. It cannot be assumed that the agency, authorities, or communities' representatives know what type of structures are most appropriate to all users.

### **The accessibility of infrastructure**

The presence of improved water supply or sanitation does not mean that everyone has access to it <sup>(25)</sup>. Accessibility of services depends on the time, energy, money, and security. To make infrastructure accessible it has to be present in sufficient numbers, close to where it is needed, at a price affordable to all, and where it can be used and reached safely. Using the services must be as easy and comfortable as possible.

The groups that are most at risk in a society (e.g. single women, people who are older, disabled, or poor) will often suffer most because of poor accessibility, and accessibility for these groups must be taken into account during planning.

### **Financial aspects**

Improvements are more likely to be sustainable if the full costs of operation and maintenance can be borne by the users. How much people are able and willing to pay for the services must be determined in an open discussion between the people and the agency. Where people buy water from vendors the price they are already paying is an indication of what people are prepared to pay <sup>(15)</sup>. It is not realistic to say that all families will be willing to pay the same percentage of their income for water and sanitation. What people are willing to pay for improved services will depend on the importance of WES to them, how much they pay for the service already, what level of service is on offer, and their expectations from authorities or agency.

Where possible the initial costs of construction should be (at least partly) recuperated in the form of money, labour, or material. Again, the community's contribution must be adapted to what they are able and willing to provide. This has to be determined in discussions between the agency and the community, and by realistically assessing the availability of resources.

If there is a central regulating body (e.g. for a piped water supply or communal latrines), an adequate system of collecting fees must be installed. Where the infrastructure is at a household level, the family can cover its own maintenance and operation costs. If subsidies are offered, they should be used to make services accessible to people who would otherwise not be able to afford them. To prevent abuse, the policy for allocating subsidies must be transparent <sup>(23)</sup>.

### **Institutional aspects**

The agency does not plan and run projects on its own. It usually works with one or several governmental bodies. Other authorities or organisations will often be given the responsibility to implement the project, or operate or maintain infrastructure.

It is important to identify all the organisations that are, or could be, connected to the project. They have to be assessed on their organisational skills, capabilities, level of motivation, availability of time as well as their access to resources, transport, and materials. Transparency and accountability will be important issues. Training or help buying materials will be necessary.

The general guidelines and regulations of the country have to be followed, and the project should fit as closely as possible in the programmes, plans, or guidelines of the government or other organisations.

### **4.4 Health, poverty, and development**

Health in a population is linked to many factors. The general environment <sup>(79)</sup>, housing, legal and physical security at home and at work, education, nutrition, gender differences, access to health facilities <sup>(88)</sup> and stress <sup>(41)</sup> all play important roles in public health. Most of these factors are closely related to poverty.

The poor are usually most at risk of infection because of their degraded environment and inadequate nutrition, so they are the hardest hit when ill as they have no reserves or rights to fall back upon, have difficulty accessing medical care, and pay the most for it. Few poor people can afford to create a healthy environment with good housing, adequate water supply and (environmental) sanitation.

Disease can also be very expensive because of the direct costs (e.g. treatment, transport) and loss of income (sick people cannot work).

Poor health often leads to poverty, and poverty often leads to poor health. Once people are in this vicious circle, it is very difficult to escape. Most people in developing countries live in poverty. In 1993 it was estimated that half of the over 1.5 billion people who inhabit cities live in extreme poverty <sup>(81)</sup>.

Poverty, and with it poor health, is not only crippling for individuals, it is a serious handicap to developing countries as a whole. Improving environmental hygiene, water supply, housing, education, nutrition, and health facilities is only possible if

resources are available. But as a large proportion of their population already suffers from disease, these countries do not have the productive workforce needed to create these resources <sup>(1)</sup>.

While general access to an adequate water supply and acceptable (environmental) sanitation are crucial to good health in a population, the only long-term solution to poor health and underdevelopment is poverty reduction. The only way the poor can afford and maintain better services (wells, piped water, improved latrines) is by increasing their income <sup>(78)</sup>. Remember this when planning a programme, and address poverty wherever possible.

## Chapter 5

### **Domestic water supply**

Domestic water supply means the source and infrastructure that provides water to households. A domestic water supply can take different forms: a stream, a spring, a hand-dug well, a borehole with handpump, a rainwater collection system, a piped water supply with tapstand or house connection, or water vendors.

Households use water for many purposes: drinking, cooking, washing hands and body, washing clothes, cleaning cooking utensils, cleaning the house, watering animals, irrigating the garden, and often for commercial activities. Different sources of water may be used for different activities, and the water sources available may change with the seasons.

There is always some kind of water source present where people live, as they could not survive without one. The source may be inadequate, however; it may be far away, difficult to reach, unsafe, or give little water, making it inaccessible or unavailable. It may give water of poor quality.

Although both problems play an important role in people's health and well-being, the availability of water is often more important than quality.

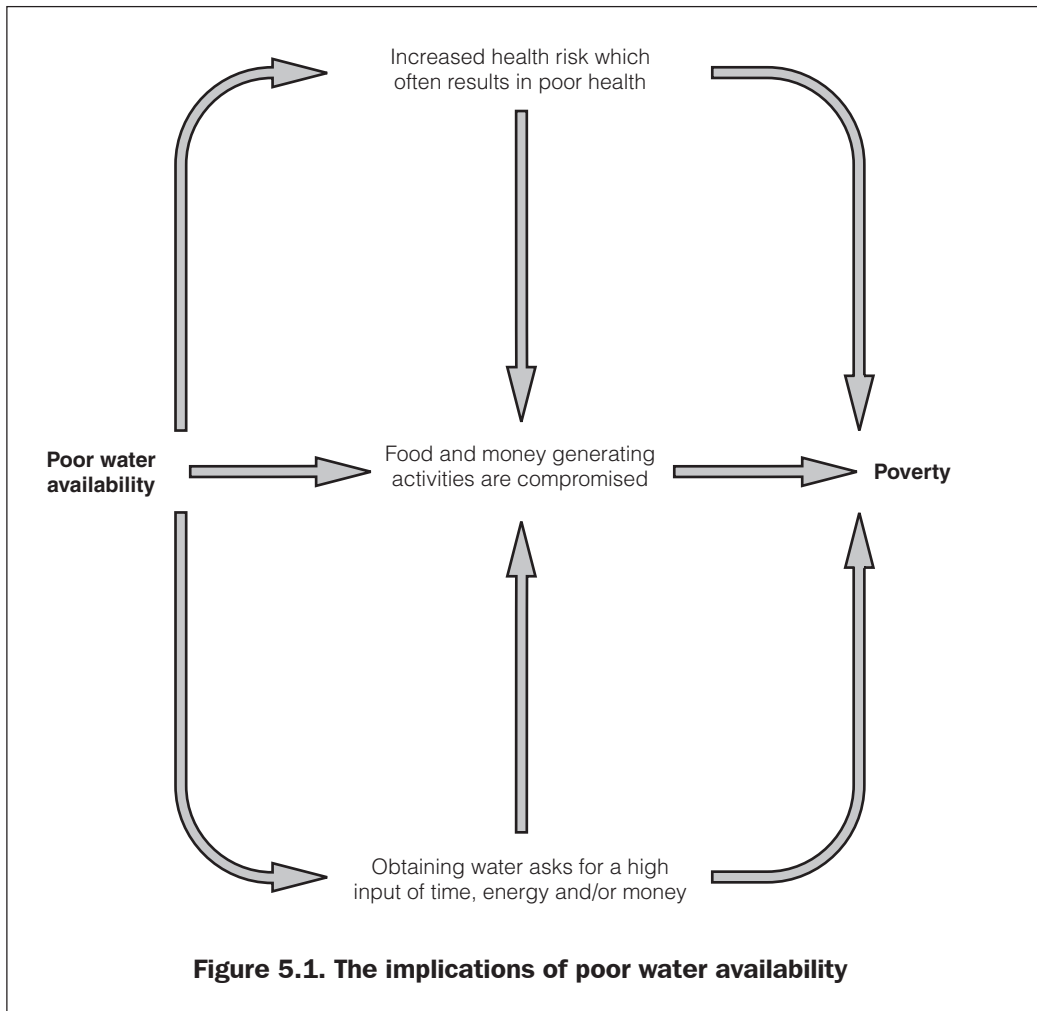
#### **5.1 Water availability**

Whether water is available or accessible to people depends on the time, energy, and/or money they have to invest to obtain it. Water from a handpump that is 25m from the but always has a long queue may be as inaccessible as water from a river 1.5km away or water that has to be bought. In addition, safety problems, such as mines or a hostile population near the water may also limit accessibility.

#### **Issues on water availability other than health**

If water availability is poor, people will lose time, energy, or money that could have been invested elsewhere. If the supply is limited, people will have to be

## DOMESTIC WATER SUPPLY



selective about what they use the water for. Figure 5.1 shows the implications of poor water availability to people.

Where water availability is insufficient, an effort should be made to improve the supply. It is important to ensure that making more water available to some does not take it away from others.

If a limited number of water sources are available, the areas around the sources may become degraded if too many people or animals use them. If unsustainable amounts of water are extracted, the environment may become degraded through falling groundwater levels or surface water sources such as rivers or streams may dry up. Be careful to ensure that short-term gain does not result in long-term loss.

### **5.1.1 Water availability and disease transmission**

Poor personal hygiene favours disease transmission. The transmission of many infections can be prevented both by washing hands and by washing body and clothes. These infections are called the water-washed diseases.

People need access to enough water to be able to maintain good personal hygiene. Although good access to water does not automatically result in good personal hygiene, poor water availability will usually result in poor personal hygiene. Once there is enough water, health and hygiene promotion will often be needed to improve personal hygiene practises.

#### **5.1.1.1 Handwashing**

Contaminated hands can carry pathogens to where these can enter the body. Hands contaminated with faecal matter can transmit faecal-oral pathogens to food, water, or directly to the mouth. The soil-transmitted helminths that cause roundworm infection and trichuriasis can be transmitted if hands are contaminated with soil containing their eggs. Hands contaminated with the discharge from the eyes of people suffering from conjunctivitis or trachoma, or the contagious liquid from papules of people with yaws, can transmit these infections to other people through direct contact.

Washing hands after every contact that could potentially pick up the pathogen, and before doing anything that could transmit the pathogen onward, can prevent transmission. Faecal-oral infections can largely be prevented if hands are washed after defecation, after coming in contact with animals, and after contact with anything that could be contaminated with faeces. In addition, hands should be washed before preparing or handling food, and before eating.

Washing hands after contact with soil or anything contaminated with soil and before handling food can reduce the risk of transmitting helminths.

The transmission of trachoma and conjunctivitis can often be prevented by washing hands after touching a person's face or after handling material used to wipe somebody's eyes or face, and before coming into contact with another person's face or eyes. The risk of transmitting yaws can be reduced by washing hands after contact with contaminated skin or material.

Washing hands removes the pathogens as well as the dirt containing and protecting the pathogens <sup>(7)</sup>. How effective handwashing is depends mainly on how thoroughly the hands are rubbed, and for how long. Water alone is not as effective

as water with a handwashing agent such as soap or ash, which are both effective in removing pathogens from hands.

The number of pathogens will be reduced significantly if the hands are rubbed with a handwashing agent for at least 10 seconds and then rinsed with water <sup>(33)</sup>. Table 5.1 shows the groups of infections associated with poor handwashing.

#### 5.1.1.2 Hygiene of body and clothes

Several pathogens can be transmitted through infectious skin or contaminated clothes. Certain vectors of disease live on clothes, or prefer people with a poor personal hygiene. All infections that spread by direct contact can be transmitted via direct person-to-person contact through contaminated skin or clothes.

Conjunctivitis and trachoma can be transmitted through infected skin, clothes, or other contaminated material that came in contact with infectious eye discharges. Several other infections transmitted through direct contact affect the skin, and the pathogens can be spread simply through direct skin contact, including yaws, scabies, and tinea.

Body lice, the vector of louse-borne typhus, louse-borne relapsing fever, and trench fever live on people's unwashed clothes <sup>(61)</sup>. Fleas, which transmit plague and murine typhus fever prefer people with poor personal hygiene <sup>(73)</sup>. Keeping body and clothes clean will reduce the transmission risk of all these infections.

The disease groups linked to poor hygiene of body and clothes are shown in Table 5.1.

Table 5.1. Disease categories associated with poor personal health									
Risk-factors related to poor personal hygiene	Faecal-oral infections Schistosomiasis Water-based with two intermediate hosts Soil-transmitted helminths Beef and pork tapeworm Leptospirosis Guinea-worm infection Spread by direct contact Vector-borne infections								
Poor handwashing				(a)	(b)				
Poor hygiene of body and clothes								(c)	

(a) : the ingested soil-transmitted helminths: roundworm infection and trichuriasis

(b) : only cysticercosis

(c) : louse-borne and flea-borne infections

### 5.1.2 The health impact of improved water availability

Table 5.2 shows how improving the water availability and personal hygiene of people will reduce transmission of some infections.

<i>Disease (group)</i>	<i>Reduction in occurrence</i>	<i>Remarks</i>
Diarrhoea	20% <sup>(26)</sup>	increase water availability (handwashing)
Infant diarrhoea	30% <sup>(32)</sup>	wash hands with soap after defecation and before eating
Roundworm	12-37% <sup>(26)</sup>	increase water availability (handwashing)
Trachoma	30% <sup>(26)</sup>	increase water availability (washing of hands and face) <sup>(3)</sup>
Yaws	70% <sup>(29)</sup>	increase water availability (washing of body)
Louse-borne typhus/ relapsing fever	40% <sup>(29)</sup>	increase water availability (washing of clothes and body)

### 5.1.3 Practical issues concerning water availability

Ideally, all users should have a convenient, culturally acceptable source that provides an unlimited amount of water at an affordable price and without degrading the environment. In practise, it will rarely be possible to provide this, and a compromise will have to be made which takes into account the local social, cultural, physical, financial, and environmental constraints.

The amount of water that people need, or use, will depend on its availability and what it is used for. Factors that influence water use include the socio-economic status of the users, whether and how people have to pay for the water, whether water is easy to get, and whether water is used for special activities (e.g. irrigation of vegetable gardens, watering of animals). Table 5.3 presents figures on water needs and demands and shows the amount of water people need and how development will change water demand. Future changes in population and development level will have to be considered. Water is lost during distribution, and this will have to be taken into account when looking at how much water must be provided to a population.

In the initial phase of an emergency internally displaced people and refugees will need a minimum of three to five litres per person per day to survive, and as soon as possible this will have to be increased to 15 to 20 l/p/d to allow for water for personal hygiene <sup>(21)</sup>. In a stable situation, the minimum amount of water available to people should be 25 l/p/d<sup>(68)</sup>.



## DOMESTIC WATER SUPPLY

**Table 5.3. Water needs, demands, and losses**

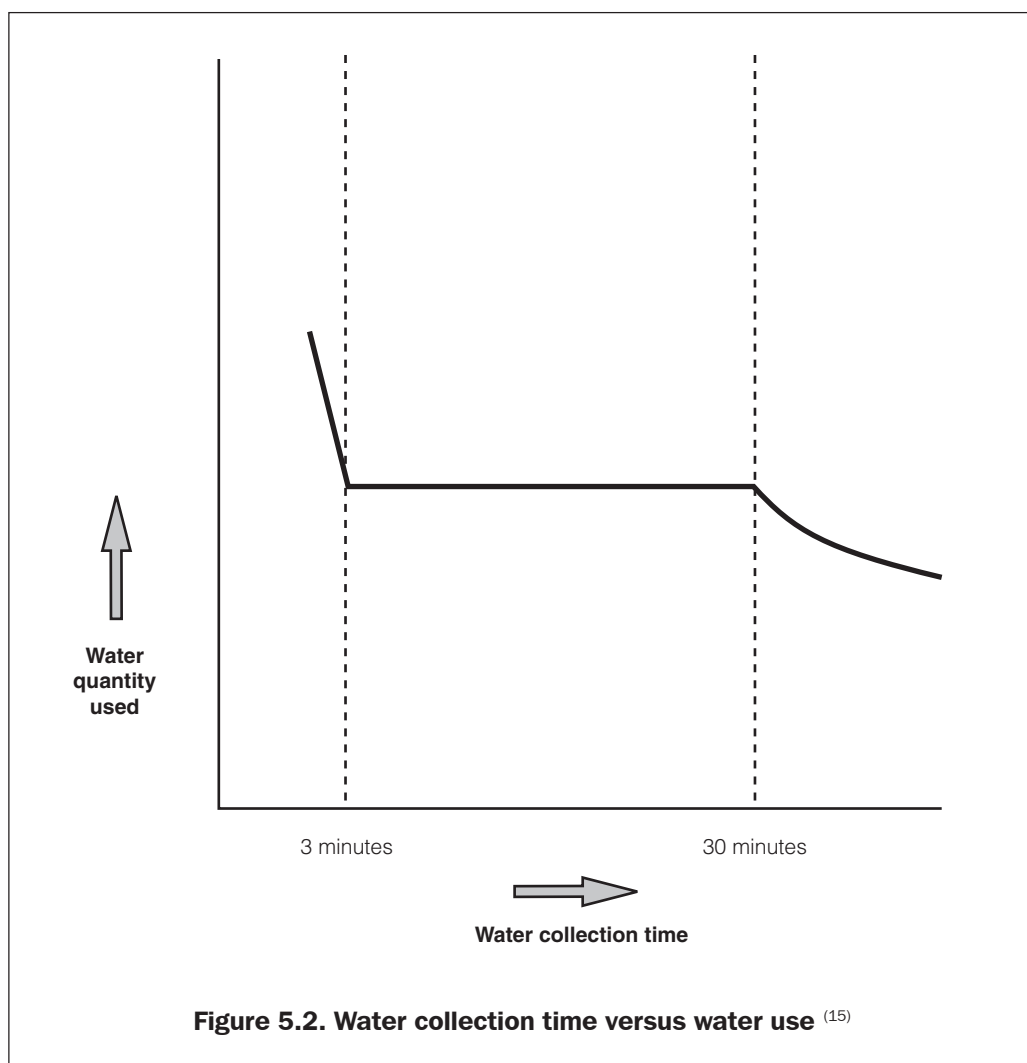
<b>People</b> (in litres/person/day (l/p/d)) <sup>(21,68)</sup> Minimum survival 3-5 Drinking and cooking needs 8-10 Minimum supply required 15-20		<b>Institutions</b> (in l/p/d) <sup>(21,66,68)</sup> Health centre, out-patients 5 Health centre, in-patients 40-60 (without laundry) Cholera treatment centre 60 Therapeutic feeding centre 15-30 School 25	
<b>Livestock</b> (in litres/animal/day) <sup>(21)</sup> Cattle 20-40 Donkeys, horses 10-40 Sheep, goats 1-5		<b>Other</b> <sup>(21)</sup> Irrigation 3-6 l/m <sup>2</sup> /day	
<b>Standpipe supply</b> (in l/p/d) <sup>(68)</sup> Rural, village control 45 Rural, washing, laundry on site 65 Urban, no payment 70+		<b>Water losses in supply systems</b> In a medium to large distribution system in reasonable condition: 15-25%. In old system with mains in poor condition: 35-55% <sup>(68)</sup> In a water trucking scheme: around 20% <sup>(21)</sup>	
<b>Household connection</b> (in l/p/d) <sup>(68)</sup> Low income, unreliable supply 50-55 Low income, metered supply 70-90 Low income, no payment 130+ Middle income 180 High income 240			

### Water collection time and use

The collection time of water is a good indicator of water availability as it takes into account distance, waiting times, and to a certain extent the effort needed to obtain water. Studies have shown that people will not really restrict their water use if collection times are less than three minutes, or a distance of about 100m in easy terrain with no waiting times. Longer collection times will result in a restriction on the use of water.

Interestingly, the amount of water collected if the collection time is between three and 30 minutes remains constant. This means that if it takes eight minutes to fetch water, the amount of water used will be more or less the same as if it took 20 minutes to collect it. If collecting water takes more than 30 minutes (i.e. a distance of roughly 1km), the amount of water used decreases again <sup>(15)</sup>. Figure 5.2 plots water collection time against the quantity of water used.

The largest health benefit from an improved water supply will result if collection times are below three minutes. Although bringing the water collection time down from 25 minutes to six minutes will result in an important saving in time and energy (in itself a large benefit), but will probably not reduce water-washed infections.



To avoid long waiting times at the sources, their numbers and yield must be sufficient. There should be a maximum of 500 to 750 people using each functional handpump, and 200 to 250 people per tap. If tapstands with multiple taps are used, no more than six to eight taps per tapstand should be installed <sup>(47)</sup>.

The minimum flow at a supply should be around 7.5 litres per minute <sup>(66)</sup>. During all seasons the sources' yield should be high enough, and seasonal changes in supply must be taken into account.

If a source has a low but constant yield it may be possible to collect the water in a reservoir (e.g. a spring box) then put a tap on the reservoir.

### Storing water

Water is only available if it is at hand when needed. Unless the source is on the household plot, access to water is limited. This problem can be overcome by storing water on the plot.

Where the water supply is unreliable (e.g. harvesting rainwater, piped water with intermittent supply) storage improves availability when water is not accessible.

An additional advantage of storing water is that the water quality improves over time. If water is stored for one day over 50 per cent of the bacteria will die. Suspended solids, which can contain pathogens, will often settle out during storage. By pouring the clear water out carefully, the settled solids can be separated from the water <sup>(64)</sup>.

Vessels that can be used to store water include local traditional clay pots, mortar jars, ferrocement tanks, and plastic or fibreglass vessels or tanks.

To avoid contamination vessels or reservoirs used for drinking-water should have a small opening or tap to prevent people from dipping the water out. The vessel should be covered with a clean, tight lid to keep animals, insects, and contaminated material out. If the water is not used for drinking, the way it is extracted is less important, but as *Aedes* mosquitoes – vector of yellow fever, dengue fever, and several other arboviruses and filariasis – can breed in household reservoirs no matter what their size, all water reservoirs should be covered properly.

How much water should be stored will depend on the situation. In general the less reliable the supply, the more effort needed to obtain the water, and the higher the water need, the larger the storage capacity should be. If there is a reliable, continuous piped water supply with a house connection then storage will not usually be necessary; but if people rely on rainwater storage needs may be large. Where there is a reliable source throughout the year, a storage capacity equivalent to the amount of water used in one to two days is probably adequate.

In addition to water storage vessels, households usually need vessels to transport water. These should be made so that carrying the water is as easy and comfortable as possible. The vessels should be covered with a clean cover or lid, and the water should be poured instead of dipped out.

In emergency situations it is often necessary to distribute water vessels so that people can collect and store water. The minimum for each household is two water containers of 10-20 litres for collecting water, and an additional 20 litres for household storage <sup>(66)</sup>.

## 5.2 Water quality

Water quality includes the physical quality (e.g. turbidity), the chemical quality (e.g. content in salt), and the microbiological quality (whether it contains pathogens). Here we will only look at the microbiological quality of the water.

### Water quality issues other than health

The presence of pathogens in water will not usually cause any problems other than health.

If the water is treated, polluting sludge (e.g. the sludge produced during coagulation) may be produced.

#### 5.2.1 Water quality and disease transmission

Water can transmit pathogens directly to people in two ways. The pathogens may be water-borne and the disease is transmitted through drinking-water, or the water may contain pathogens which can penetrate the skin.

Faecally polluted drinking-water can transmit faecal-oral infections. The transmission route is direct from person (or animal) to person. These pathogens may contaminate the water at the source, but contamination may also occur during the transport, distribution, or handling of the water.

Transmission of the Guinea-worm is more complex. People infected with Guinea-worm will have a blister on their skin. If the blister comes in contact with water, it bursts and discharges the worm's larvae. These larvae can infect *Cyclops* (a water flea), inside which they develop. People become infected when they ingest *Cyclops* through drinking-water. Guinea-worm infection cannot be transmitted directly from person to person. The water will be contaminated at the source, and if the water at the source is safe, contamination at a later stage is not very likely.

If water containing a particular species of snail is contaminated with urine or faeces from infected people, schistosomiasis can be transmitted. This pathogen can penetrate the skin of people who are in direct contact with the contaminated surface water.

If water is contaminated with the urine of animals infected with leptospirosis, the pathogen can be transmitted through direct skin contact with the water. Rats are the main reservoir of leptospirosis.

Table 5.4 presents the different disease-groups linked to water of poor quality.

**Table 5.4. Infections associated with poor water quality**

Risk-factors related to poor water quality										
	<div> <div>Faecal-oral infections</div> <div>Schistosomiasis</div> <div>Water-based with two intermediate hosts</div> <div>Soil-transmitted helminths</div> <div>Beef and pork tapeworm</div> <div>Leptospirosis</div> <div>Guinea-worm infection</div> <div>Spread by direct contact</div> <div>Vector-borne infections</div> </div>									
i Contaminated with excreta	H/A									
Contaminated by Guinea- worm							H			
ii Contaminated with excreta		H/A				A				

H: human host

A: animal host

### 5.2.2 The health impact of improved water quality

Contaminated drinking-water is just one of the potential transmission routes of faecal-oral infections, which can also be transmitted by food or hand-to-mouth contact. Where faecal-oral infections are endemic, and sanitation, handwashing practise, and food hygiene are poor, the majority of cases will probably not have resulted from drinking contaminated water. In contrast, where faecal-oral infections are common, and sanitation, handwashing practise and food hygiene are adequate, the role of drinking-water in the transmission of faecal-oral infections is probably important <sup>(15)</sup>.

As Table 5.5 shows, improving water quality in unsanitary neighbourhoods will probably not really affect levels of (infant) diarrhoea, while improving the water quality in ‘clean’ neighbourhoods probably will reduce it <sup>(70)</sup>. Water quality is

**Table 5.5. Reduction in infections associated with improved drinking-water quality**

<i>Disease (group)</i>	<i>Reduction in occurrence</i>	<i>Remarks</i>
Diarrhoea	15% <sup>(26)</sup>	
Infant diarrhoea	negligible <sup>(70)</sup>	if neighbourhood sanitation is poor (open defecation in neighbourhood)
	40% <sup>(70)</sup>	if neighbourhood sanitation is good (no open defecation in neighbourhood)
Guinea-worm infection	78% <sup>(26)</sup>	

especially important in an urban or peri-urban environment, where water supplies are often at risk of pollution, and the risk of large outbreaks is higher than in a rural environment<sup>(15)</sup>. As Guinea-worm will normally only be transmitted through drinking-water, improving the drinking-water quality at the source is very effective in controlling the infection.

The quality of the water used for washing hands, body, and clothes is not really important as long as it is not heavily polluted. The risk of transmitting pathogens other than schistosomiasis<sup>(15)</sup> and leptospirosis during bathing in surface water is limited.

Animals do not need water of very high quality, but most domestic animals can be infected with faecal-oral infections, and cattle and pigs can be infected with beef and pork tapeworm, so their water quality should be as high as possible.

### **5.2.3 Practical issues concerning water quality**

This section looks at some general points on water sources, storage and distribution, treatment, and water quality assessment in the field.

#### **Water sources**

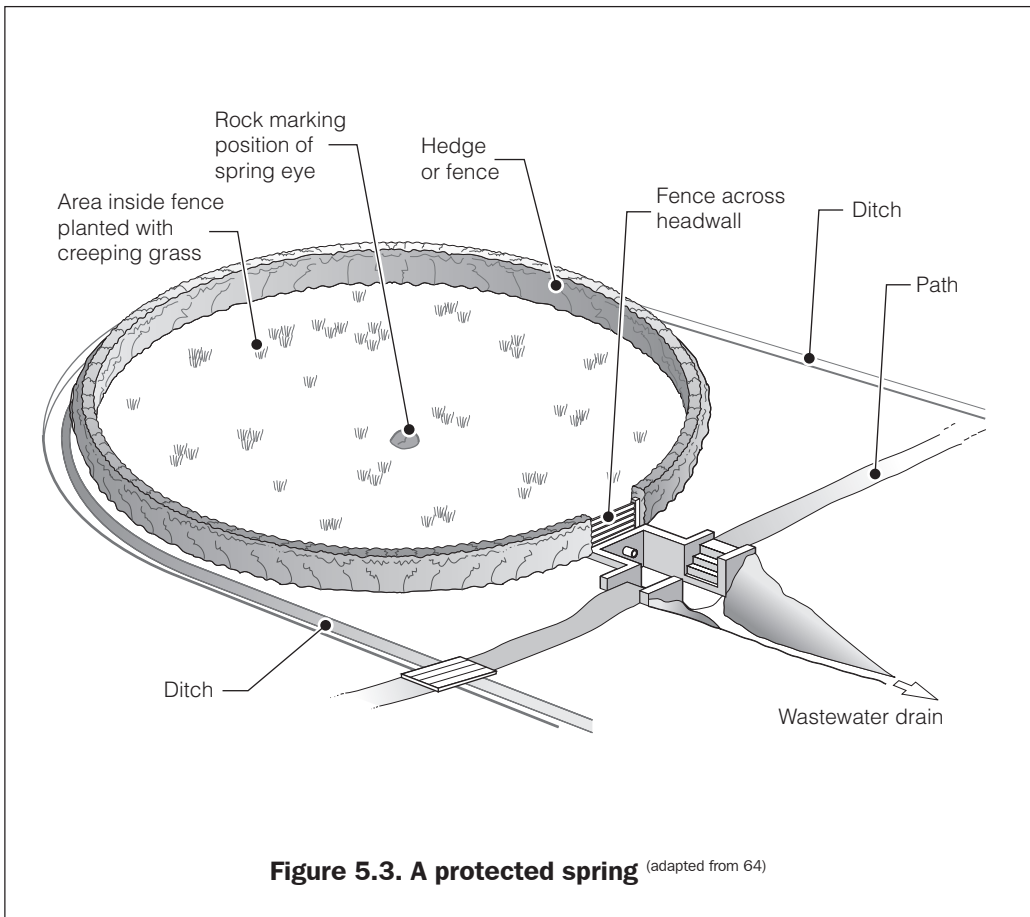
One of the priorities in selecting a water source is quality. The quality and protection of the source is important regardless of whether the water will be treated or not. Good quality water needs less, or no, treatment; and if treatment fails there will be fewer health risks. Sources must be protected from pollution by installing adequate structures for protecting, collecting, and distributing the water. Health and hygiene promotion will probably be needed to make people aware of the importance of protecting the water source.

Water can be obtained from several different types of source.

**Springs:** An adequately protected spring will normally produce good quality water. Building a proper headwall, access structures, and drainage system will prevent degradation. Latrines should not be sited above the spring, and a hedge or fence should keep animals at least 10 metres away from the area above the spring. A ditch should be dug close to the fence to divert runoff. Figure 5.3 shows an example of a protected spring.

If a spring has a low yield, a spring box might be constructed to collect and store water that can then be withdrawn through a tap. The spring box should be well constructed, and all openings (e.g. man-holes, overflow pipes) should be closed securely or covered with fly screen.

## DOMESTIC WATER SUPPLY



**Rainwater harvesting:** If rainwater is properly collected and stored it will usually be of good quality. The catchment area (e.g. roof, rock) and guttering or channels should be kept as clean as possible. The first minutes of rainfall are best discarded to avoid collecting unwanted material like dust, debris, or bird droppings. Alternatively, a silt trap can be installed. The storage tank must be built to prevent contamination by animals, insects, or polluted material <sup>(56)</sup>. The water should be withdrawn from the storage tank by a tap or pump to avoid contamination during collection. Rainwater is seasonal and large storage capacity is needed to bridge dry periods, so rainwater harvesting is not usually appropriate as the only source of water.

**Borehole or tube-well:** A properly constructed borehole with handpump usually produces good quality water. The tube-well should be sited a safe distance from sanitary structures. To avoid the seepage of contaminated surface water or shallow

groundwater into the tube-well, install a good grout seal. A watertight apron sloping away from the pump must extend for at least 1 metre around the tube-well. The borehole casing must be intact or else polluted water could enter. If water must be added to prime a suction pump, be careful to use clean water to avoid contaminating the water in the tube-well <sup>(43)</sup>. The apron must drain into a drainage channel that leads spilt water at least 4 metres away from the tube-well before disposing of it in a garden or soakaway. If possible, a fence or hedge should be installed around the borehole to keep animals at distance <sup>(82)</sup>.

It is very difficult to assess whether the underground structures of existing tube-wells are adequate, and it is therefore best to assume that they are not. The apron and drainage channel should be intact and not have any cracks. There should be no ponding of water within 2 metres of the borehole, and no excreta (human or animal), refuse, or surface water should be within 10 metres of the tube-well <sup>(82)</sup>. A sanitary survey would identify any of these as risk factors that might contaminate the water in the tube-well.

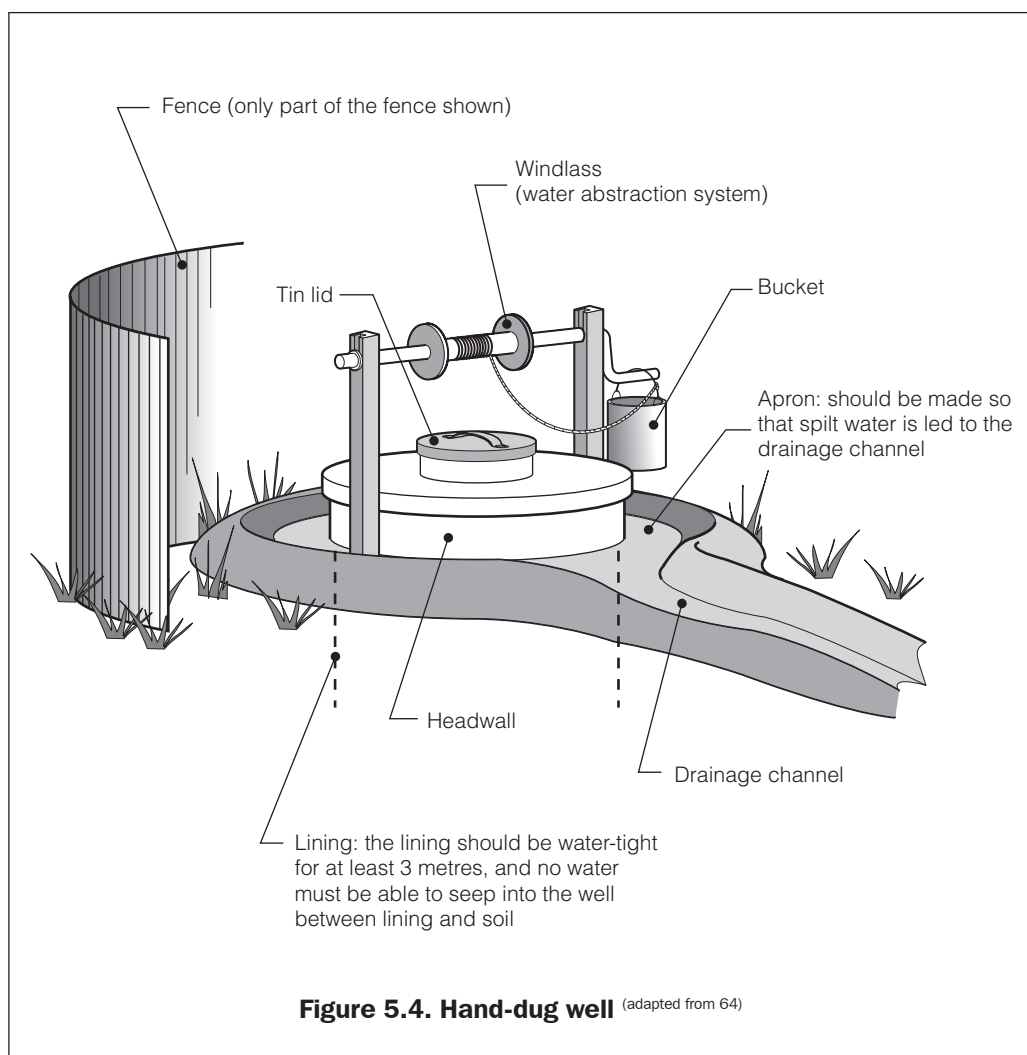
**Hand-dug wells:** Water abstracted from a hand-dug well is usually of intermediate quality. Sanitary structures should be sited at sufficient distance from the well. The top three metres of the well lining must be watertight to prevent polluted surface water or shallow groundwater from seeping into the well. A space is often created during construction between the original soil and the lining. This must be properly sealed to prevent surface water from entering the well. There should be a watertight apron at least one metre wide around the well <sup>(82)</sup>, and a drainage channel at least four metres long must lead spilt water away before discharging it properly <sup>(64)</sup>.

If possible, water should be withdrawn using a system that prevents the vessel and rope from being contaminated (e.g. by being left on the ground). A headwall must be installed to prevent surface water or other contamination from entering the well. The headwall should discourage people from standing on it, as this could result in soil or spilt water contaminating the well. Children must be prevented from throwing material in the well <sup>(15)</sup>. Where possible, a fence or hedge should be installed to keep animals at distance. Figure 5.4 shows an appropriate hand-dug well.

If a hand-dug well is covered with a lid and a handpump is installed, several risk factors are eliminated or reduced. A raised manhole should be installed to ease maintenance, and to allow people to get to the water without demolishing the structure if the pump breaks down.



## DOMESTIC WATER SUPPLY



If existing wells are assessed in a sanitary survey, it is best to assume that the underground structures are not adequate. Risk factors to look for include broken or cracked apron and drainage channel, ponding of water within two metres of the well, and the presence of human or animal excreta, refuse, or surface water within 10 metres of the well <sup>(82)</sup>.

**Surface water:** Any type of surface water must be assumed to be polluted or at risk of pollution. If surface water has to be used for drinking-water, the water should be abstracted as far upstream as possible. The river water will be less contaminated upstream of where people bathe, wash, or play in a stream, and animals come for watering. The quality of surface water can be improved by

installing infiltration galleries in the riverbed or by digging riverside wells or infiltration wells <sup>(21)</sup>.

When selecting a water source, seasonal fluctuations in water availability have to be considered. Surface water, water from shallow wells, and rainwater are all usually influenced by the seasons, and water may be in short supply at the end of the dry season.

### **Water quality beyond the source**

Installing a water supply system that provides water of very good quality is of little use if the water is going to be contaminated at a later point. It is very common for water to be contaminated with faecal-oral pathogens during distribution, transport, collection, storage, or handling <sup>(48)</sup>.

Distribution points, vessels, and reservoirs must be designed so that the risk of contamination during filling is minimal. Transport and storage vessels should have a small neck so that water cannot be dipped out. (Be practical, however, as the difficulty of filling a vessel with a small neck at a handpump must be considered.) The vessels should be properly covered to keep animals, insects, dust and other contaminants out. The water should be taken from the vessel either by pouring, or by using a tap. Vessels used for transporting and storing drinking-water should only be used for this purpose. If they have been used for something else, or have been empty for some time, they must be properly cleaned and possibly disinfected before being used for drinking-water. Vessels can be cleaned with boiling water or a chlorinated solution. Health and hygiene promotion will probably be needed to improve behaviour concerning water handling and storage.

A piped water system with intermittent supply is also at risk of pollution. Intermittent supply means that the pressure in the pipes will occasionally be lower than the pressure in the surrounding soil, which means that contaminated water can seep back into the pipes. Installing an electric pump to draw water from a piped water supply with a low water pressure, as often happens in cities in developing countries, can draw polluted water into the system.

### **Water treatment**

The term water treatment is used here to mean manipulating the water to remove water-borne pathogens (e.g. those that cause diarrhoeal diseases). This will often be accomplished by chlorinating the water.

It is not always obvious whether water needs to be treated or not. It is more important to treat the water when many people are supplied by the same source,

the water is contaminated, there is a risk of an outbreak of water-borne disease, and polluted water is playing a role in the occurrence of water-borne infections. In addition the local technical, financial, institutional, and logistical capabilities will have to be assessed to determine whether the capability exists to treat the water adequately. This assessment must look into both the current and future situation.

Water treatment at communal level requires funds and adequate support, while treatment at household level will rarely be reliable. The priority should therefore be to find a source that provides water of an adequate quality, and to maintain this quality by protecting the source.

Water from safe sources used by small communities does not usually need to be treated. The priority should be on health and hygiene promotion to both protect the source and handle and store the water properly.

A piped water supply to (peri-)urban areas should normally be chlorinated to reduce the risks of water-borne outbreaks of faecal-oral infections. In an emergency situation, water should be chlorinated if it is piped to more than 10,000 people. Water should also be chlorinated if an outbreak of faecal-oral infections is occurring, or if there is a risk of an outbreak <sup>(66)</sup>. Other than in emergencies or during a significant threat of an outbreak of faecal-oral disease, there is little use in introducing a water treatment system that could not be maintained when external support is withdrawn <sup>(15)</sup>.

Although it is not possible to go into much detail on water treatment here, there are some important points concerning chlorination and boiling of water.

Chlorine added to water will work in three ways:

- Part of the chlorine will oxidise contamination, including pathogens. The more contamination there is, the more chlorine will be used up. This is 'consumed chlorine'.
- Part of the chlorine will combine with matter in the water, and form 'combined residual chlorine'. Combined residual chlorine functions as a disinfectant, but is less effective than 'free residual chlorine' <sup>(15)</sup>.
- Part of the chlorine will form free residual chlorine. The free residual chlorine has a remaining or residual effect in water. If pathogens contaminate the water during distribution, handling, or storage, the free residual chlorine in the water will normally kill them.

Proper chlorination therefore has two effects: it kills pathogens present in the water at the time of treatment, and it will, to some degree, protect water from future contamination.

Normal chlorination of drinking-water is not effective against the cysts of faecal-oral protozoa (amoebiasis, giardiasis, cryptosporidiosis, and balantidiasis) <sup>(3)</sup>.

In chlorinating drinking-water enough chlorine must be added to leave sufficient free residual chlorine without giving the water a bad taste or wasting the product. Normally a free residual chlorine content of 0.2-0.5mg/l at the point of distribution is adequate <sup>(22)</sup>. Annexe 4 shows how to determine the amount of chlorine that must be added to water.

After the chlorine is added, it needs time to react with the contamination and turn into combined residual chlorine. A contact time of at least 30 minutes should therefore be allowed before the water is safe to drink, or before the free residual chlorine can be measured. In a cold climate chlorine acts more slowly, and the contact time will have to be longer <sup>(15)</sup>. If the pH of the water is high, chlorine is less effective in killing pathogens. At a pH of over 8, the free residual chlorine content of the water should be between 0.4 and 1.0mg/l <sup>(22)</sup>.

Sometimes the boiling of water is promoted to make it safe. To be certain that all pathogens are dead, water has to be boiled for 5-10 minutes, although bringing water above 75°C will normally kill the vast majority of the pathogens <sup>(28)</sup>. Unlike chlorination, boiling water is effective on water of high turbidity, and against protozoa. Boiling water has several disadvantages though, which often makes it less useful than chlorination. Around 1kg of firewood is needed to boil one litre of water, which will often make it environmentally and financially unsustainable. And unlike chlorinated water, boiled water has no residual effect against pathogens <sup>(21)</sup>.

### **Assessing water quality**

In the field there are two ways to assess water quality: conduct a sanitary survey in which all threats to the quality of water are evaluated, or test the water for specific bacteria (usually faecal coliforms and total coliforms) to check whether the water is contaminated. Testing for bacteria is relatively costly and complex, and some skill is needed to obtain reliable results. It also only indicates water quality at the time of the test. Although a sanitary survey does not give a measurable level of pollution, it is often more appropriate than bacterial testing as it does not need specialised material, is instant, and gives a more holistic view of the water quality and its threats.

Treated water should be free of any coliforms when it enters the distribution system. At the distribution point treated water should contain no faecal coliforms. The presence of (faecal) coliforms in treated drinking-water is an indication that treatment is not working properly, or that the water is being contaminated during distribution. Instead of determining which coliforms are present, it is often enough to verify that the water has a sufficient level of free residual chlorine, and that there has been enough contact time between the chlorine and water.

Unlike treated water, any source of untreated water can be expected to contain faecal coliforms, and it will be virtually impossible to obtain water free of faecal coliforms without treatment <sup>(15)</sup>. In rural areas it will often be difficult to reach WHO or national guidelines even with appropriate structures.

### **5.3 Additional health issues concerning water supply**

A water supply can be a health threat because of its structure or because of poor design or maintenance. The main health risks will be a result of creating an environment in which vectors or intermediate hosts can breed or live.

#### **5.3.1 Large water reservoirs**

Artificial reservoirs used for water storage can create two major health problems. The reservoirs are potential breeding sites for *Anopheles* mosquitoes that transmit malaria and filariasis <sup>(36)</sup>, and if people come in direct contact with contaminated water schistosomiasis can also be transmitted. An additional health risk could be created if the spillway of the reservoir creates shallow, turbulent, ‘white water’ in which the blackfly, the vector of river blindness, can breed <sup>(232,240)</sup>.

#### **5.3.2 Water distribution and storage**

All water reservoirs used in the distribution or storage of water (e.g. service reservoirs, overhead tanks, small domestic water containers) should be adequately covered and maintained to prevent them from becoming breeding sites for *Anopheles* mosquitoes and *Aedes* mosquitoes <sup>(80)</sup>.

#### **5.3.3 Sullage**

Chapter 7 goes into more detail on drainage, so here we will only briefly point out the health risks associated with the disposal of sullage (or domestic waste water).

All water supply systems will produce waste water in the form of used water, water spilled at the distribution point, and water leaking from pipes or taps. Although sullage normally contains fewer pathogens than sewage, it will often

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contain faecal pathogens, and could potentially transmit excreta-related infections to either people or animals.

If the casings or linings of boreholes or hand-dug wells are not properly sealed, waste water could seep back in, contaminating the water.

Where waste water keeps soil moist, a favourable environment for soil-transmitted helminths (e.g. hookworm and roundworm) or sandflies could be created <sup>(80)</sup>.

Accumulated polluted waste water can become a breeding site for domestic flies, which transmit several faecal-oral infections and diseases spread by direct contact. *Culex* mosquitoes, which transmit filariasis and several arboviral infections, breed in polluted waste water too <sup>(21)</sup>. *Anopheles* mosquitoes can breed in ponds or puddles formed by unpolluted waste water.

## Chapter 6

### **Sanitation**

Sanitation is everything associated with excreta\* in relation to people. It includes the structures used to deal with excreta (e.g. latrines), the materials needed to use these correctly (e.g. water), and people's behaviours and attitudes in relation to both excreta and the sanitary structures (e.g. acceptance of open defecation, washing hands after defecation).

This chapter looks at how excreta and excreta-related infections are linked, and how these infections can be prevented by improved sanitation. Several sanitation-related issues are considered in some detail, and we look at issues which are important to the planning, design, and construction of sanitary structures.

In addition to health benefits, the installation of adequate sanitation may bring people increased convenience and privacy. Improving sanitation can eliminate the unpleasant or unsightly living or working conditions which often result from poor sanitation. Where excreta is reused, people acquire a potential resource. And although this will not be the development worker's motivation, nice sanitary structures often increase the prestige of the owner.

The uncontrolled discharge of excreta, sewage, or effluent into surface water may result in environmental problems. The organic matter in excreta-related waste will use oxygen to oxidise, and it will draw its oxygen from the water. The amount of oxygen used is called the Biochemical Oxygen Demand (BOD) of the excreta. If the waste is discharged into surface water without being adequately treated, the natural aquatic life in the water may die from lack of oxygen.

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\* Excreta can be faeces and urine, and can be human as well as animal

## 6.1 The transmission of excreta-related infections

Infections are related to excreta in two ways: the pathogens leave the original host's body through excreta, or one of the vectors of the disease benefits from the lack of adequate sanitary structures or from accessible excreta.

Several disease-groups leave the body through excreta.

Faecal-oral infections are transmitted directly through faecally contaminated hands, food, water, or soil. The pathogen must be ingested to cause infection (see Section 2.4.1.1, Figure 2.2).

Schistosomiasis needs to develop in a freshwater snail before it can infect people. The pathogen infects people by penetrating skin which is in contact with infected surface water (see Section 2.4.2.2, Figure 2.4).

Water-based helminths with two intermediate hosts (e.g. fasciolopsiasis, clonorchiasis) need to develop in two freshwater intermediate hosts before they become infectious to people. Transmission occurs when the second intermediate host is eaten without being properly cooked (see Section 2.4.2.2 Figure 2.4).

Soil-transmitted helminths (e.g. hookworm disease and roundworm infection) have to develop in soil before they can infect people. Some of these helminths infect people by penetrating their skin when they are in contact with contaminated soil, others infect people when ingested (see Section 2.4.2.1, Figure 2.3).

Beef tapeworm and pork tapeworm have to be ingested by cattle or pigs and development in them. People are infected by eating poorly cooked beef or pork.

Cysticercosis, a complication of pork tapeworm, is transmitted like a faecal-oral infection from person to person (see Section 2.4.2.3).

Leptospirosis is mainly transmitted through direct skin contact with water or material contaminated with the urine of infected rats (see Section 2.4.1.2).

Vectors which benefit from inadequate sanitation include domestic flies, cockroaches, and *Culex* mosquitoes.

Domestic flies, which can transmit several faecal-oral infections including conjunctivitis, trachoma, and yaws, can breed in, and feed on, excreta <sup>(67)</sup>.



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Cockroaches, which have the potential to transmit several faecal-oral infections, can feed on excreta and hide in sanitary structures.

The mosquito *Culex quinquefasciatus*, a vector of filariasis and several arboviral infections, can breed in the polluted liquids in latrines and cesspits or septic tanks<sup>(61)</sup>.

As there are many disease-groups related to excreta and sanitation, the following concept should help to assess when these infections could pose a risk.

If pathogen transmission is to succeed, the excreta has to come in contact with certain elements. For example, schistosomiasis can only be transmitted if the pathogen infects a freshwater snail, so transmission can only occur if the excreta is released into fresh surface water.

Table 6.1 shows the different elements that the pathogens have to come in direct contact with to be transmitted.

<b>Table 6.1. Disease groups and the elements that play a role in disease transmission</b> <small>(adapted from 60)</small>										
The element excreta must come in direct contact with:										
	Faecal-oral infections	Schistosomiasis	Water-based with two intermediate hosts	Soil-transmitted helminths	Beef and pork tapeworm	Leptospirosis	Guinea-worm infection	Spread by direct contact	Vector-borne infections	
<b>People</b>	H/A				H <sup>(a)</sup>	A				
<b>Animals</b>	H/A				H	A				
<b>Insects</b>	H/A							<sup>(b)</sup>	<sup>(c)</sup>	
<b>Crops, food, vegetation</b>	H/A				H	A				
<b>Soil</b>	H/A			H		A				
<b>Surface water</b>	H/A	H/A	H/A		H	A			<sup>(c)</sup>	
<b>Ground water</b>	H/A									

H: Human excreta

A: Animal excreta

<sup>(a)</sup>: Only cysticercosis, a complication of pork tapeworm

<sup>(b)</sup>: Domestic flies can breed in excreta and can transmit conjunctivitis, trachoma, and yaws

<sup>(c)</sup>: The mosquito *Culex quinquefasciatus*, vector of filariasis and several arboviral infections, can breed in sanitary structures or surface water polluted by excreta

### ***Faecal and urinary transmission of infections***

Most excreta-related infections are only transmitted by faeces. The exceptions are urinary schistosomiasis, which is common in Africa and which has no animal host; leptospirosis, which is transmitted mainly through animal urine; and (para-) typhoid fever, which is occasionally transmitted through urine <sup>(16)</sup>.

### **The risk of children's excreta**

As many excreta-related infections occur mainly in children, it is more likely that children's excreta will contain pathogens than adult's excreta, so special care must be taken in disposing their faeces. Health and hygiene promotion to mothers will usually be needed to improve the children's behaviour and reduce the risks of open defecation by children. Sanitary structures will have to be adapted and acceptable to children.

### **The risk of animal excreta**

Many excreta-related pathogens can infect animals as well as people, and animals can be important reservoirs of disease. Cattle, pigs, dogs and rats are all potential hosts for several diarrhoeal infections, several water-based helminths, and leptospirosis. Chickens and wild birds can be the reservoir of pathogens that cause diarrhoea. More information on the potential animal reservoirs of specific diseases can be found in Annexe 1. Where animals are believed to be playing a role in the transmission of infections they will have to be controlled.

#### **6.1.1 Risk-factors relating to excreta and sanitation**

There are five major problems relating to excreta and sanitation which can result in a health risk:

- There is open defecation as people do not use sanitary structures.
- People do not wash their hands (properly) after defecation.
- Sanitary structures are not used correctly, are poorly designed, or are poorly maintained.
- Excreta is re-used as a fertiliser, fish food, building material, or for fuel.
- People come in contact with excreta of infected animals.

Several of these problems can be broken down further into specific risk-factors. These specific risk-factors with their associated disease-groups are presented in Table 6.2.

Several of these risk-factors will be looked at in more detail in Section 6.2.

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**Table 6.2. Specific sanitation-related risk-factors**

Risk-factors relating to:											
i Open defecation											
ii Poor personal hygiene											
iii Poor functioning or design of structure											
iv Excreta used as a resource											
v Animal contact											
		Faecal-oral infections	Schistosomiasis	Water-based with two intermediate hosts	Soil-transmitted helminths	Beef and pork tapeworm	Leptospirosis	Guinea-worm infection	Spread by direct contact	Vector-borne infections	
i	Sanitary structures are not used (by all)					(a)		(b)			
ii	Poor handwashing after defecation				(c)						
iii	Poor hygiene of sanitary structure				(c)			(b)			
	Openings or cracks in sanitary structure							(b)	(d)		
	Collapse of sanitary structure or pit							(b)	(d)		
	Overflowing of sanitary structure							(b)			
	Excreta discharged in surface water							(b)	(d)		
	Sanitary structure pollutes groundwater										
	Excreta is handled in O&M							(b)			
	iv	Excreta is re-used							(b)	(d)	
v	Access of animals to living quarters										
	Close contact between people and animals (work, play)										
	Animal faeces on domestic plot							(b)			
	Animals have access to well, spring, etc.										
	Animals have access to stored water or food										
	Animals have access to surface water										

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- <sup>(a)</sup>: Leptospirosis, if transmitted by excreta, is usually transmitted by animal urine and therefore almost impossible to confine through improved sanitation
- <sup>(b)</sup>: A potential for breeding and feeding of domestic flies
- <sup>(c)</sup>: A risk of cysticercosis, a complication of pork tapeworm; all other 'positives' in this column can result in both cysticercosis and in infection of cattle or pork
- <sup>(d)</sup>: A potential for breeding of the mosquito *Culex quinquefasciatus*

**Table 6.3. Reduction in occurrence of disease associated with improved sanitation**

<b>Disease (group)</b>	<b>Reduction in occurrence</b>	<b>Remarks</b>
Diarrhoea	36% <sup>(26)</sup>	improved sanitation
	42% <sup>(70)</sup>	sanitary facilities are well maintained (clean)
	44% <sup>(40)</sup>	hygiene improved in existing toilets in schools
	30% <sup>(70)</sup>	elimination of excreta from around the house
Infant diarrhoea	negligible <sup>(70)</sup>	improved neighbourhood sanitation but poor water quality
	25% <sup>(70)</sup>	improved neighbourhood sanitation with good water quality
Hookworm	4% <sup>(26)</sup>	improved sanitation only; reduction when improved sanitation and medical treatment were combined: 69%
Roundworm	29% <sup>(26)</sup>	improved sanitation and water supply; reduction when improved sanitation and medical treatment were combined: 80%
Tapeworms	important <sup>(73)</sup>	improved sanitation

### 6.1.2 The health impact of improving sanitation

Table 6.3 shows how different excreta-related infections can be reduced with improved sanitation.

### 6.1.3 The survival of excreta-related pathogens in the environment

Outside the host, excreta-related pathogens will usually die off over time. Most pathogens can remain viable in the environment for some time, however, and Table 6.4 shows the maximum time of survival of some. As a general rule, pathogens survive longer when they are in lower temperatures, in a moist environment, and protected from direct sunlight <sup>(28,31)</sup>. Again as a general rule, helminths and viruses will survive longer than bacteria and protozoa.

Except for roundworm, all the infections in Table 6.4 are faecal-oral. It is less useful to look at the survival times of pathogens which need intermediate hosts, as these usually remain viable for as long as the intermediate host survives.

**Table 6.4. Maximum survival times (in days) of pathogens in different media** (from 28)

Media in which pathogens survive (at 20 to 30°C)	Bacterial enteritis (by <i>E.coli</i> )	Salmonellosis	Shigellosis (bacillary dysentery)	Cholera	Amoebiasis	Faecal-oral viruses (e.g. polio)	Roundworm
Fresh water and sewage	60	60	30	30	30	120	many months
Faeces, nightsoil, and sludge	90	60	30	30	30	100	many months
Soil	70	70	-	20	20	100	many months
On the surface of crops	30	30	10	5	10	60	60

The health risk of contaminated material (water, food, other objects) will usually decrease over time if no multiplication or recontamination occurs. As the number of pathogens discharged is often very large, the potential for transmission can remain high, even if most pathogens die off or if the excreta is diluted in surface water. A person with cholera can defecate up to  $1 \times 10^{12}$  bacteria per litre of diarrhoea, for example, a person with urinary schistosomiasis can discharge 50,000 eggs per litre of urine, and people infected with hookworm disease can shed  $1 \times 10^6$  eggs per day <sup>(73)</sup>.

Several bacteria and helminths can multiply outside the host. The bacteria *Salmonella* spp. (causing salmonellosis and (para-)typhoid), *Shigella* spp. (causing bacillary dysentery) <sup>(3)</sup> and *E.coli* (causing bacterial enteritis) <sup>(28)</sup> can all multiply in food. The food can be contaminated through faeces, hands, utensils, domestic flies, or cockroaches. Meat and dairy products pose the greatest risk. Thus food which is not initially harmful because it contains too little bacteria can become infectious over time because the bacteria have multiplied.

Several water-based helminths (schistosomiasis, fasciolopsiasis, fascioliasis, clonorchiasis, and opisthorchiasis) can multiply in freshwater snails, and strongyloidiasis can multiply in soil. Here again, a light contamination of water or soil can become very infectious because the pathogen has multiplied outside the host.

Excreta poses a large and prolonged health risk because of its potentially high load of pathogens, the persistence of pathogens in the environment, and the potential for multiplication outside the host, so excreta-related wastes must be dealt with carefully.

## 6.2 Practical issues on sanitation

This section looks at several of the risk factors mentioned in Table 6.2. It also presents several aspects important to the planning, design, and construction of sanitary structures.

### 6.2.1 Open defecation

Open defecation allows the transmission of all excreta-related infections and is therefore a serious health threat. Open defecation is not acceptable close to the household plot, or in urban communities or other areas with high or medium population densities.

Each infected person usually has great potential to spread pathogens, so sanitary structures will only be effective in preventing disease if they are used by everyone, all the time. Even if only some people in the population (e.g. children) defecate in the open, the health benefits of sanitary structures will be limited. Some examples to illustrate this problem <sup>(adapted from 2,3,16,73)</sup>:

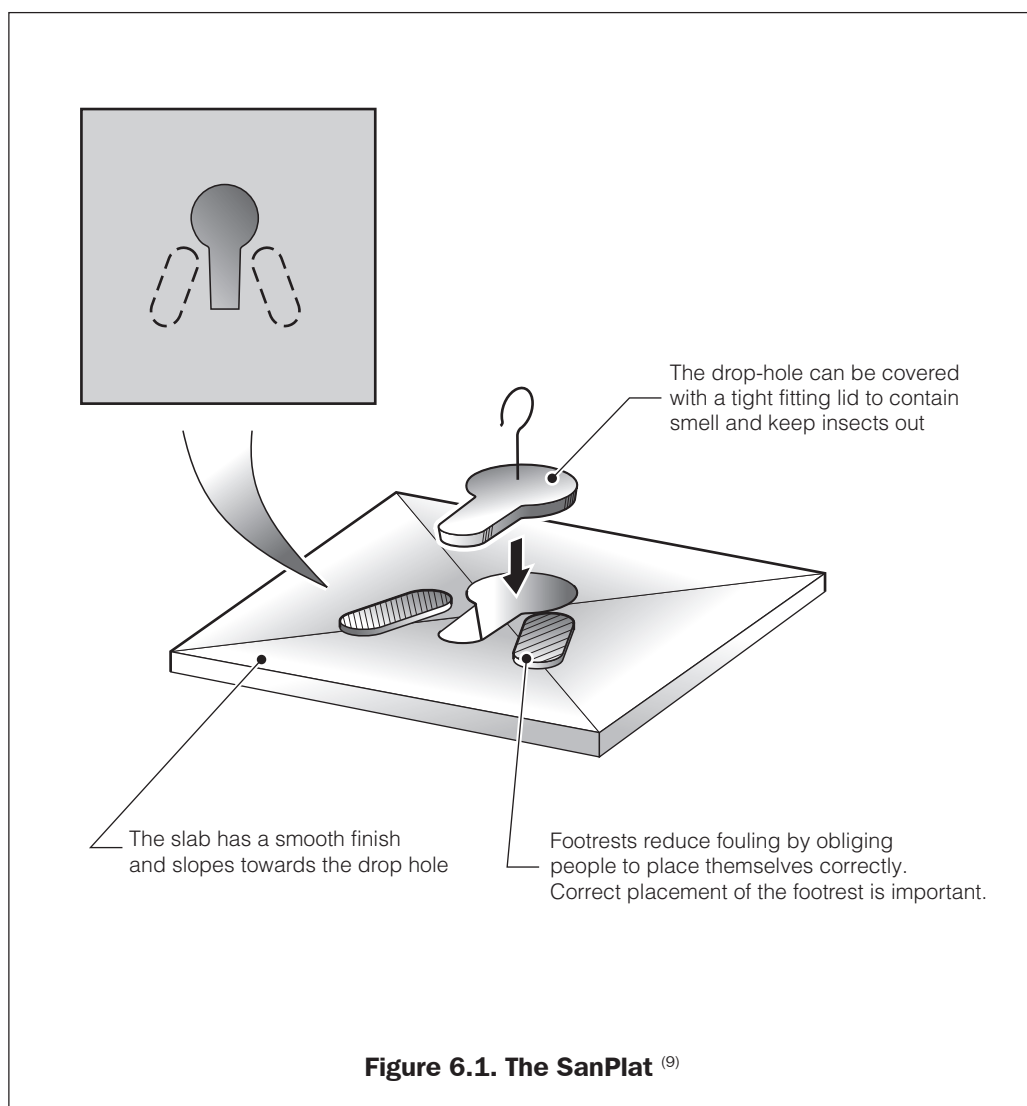
- A person with bacillary dysentery excretes  $1 \times 10^9$  bacteria in a small stream. Ingesting 10 to 100 bacteria can cause infection. The number of pathogens excreted in the water could in theory pollute  $10,000\text{m}^3$  of water with 100 bacteria per litre.
- A person with a hookworm infection can easily release 1,000,000 eggs per day. If this person does not always use a latrine, and we assume that 1 per cent of the eggs end up in favourable soil, become infectious, and remain viable for six weeks, then this person will be responsible for over 400,000 infectious larvae in the soil at any time for as long as the infection lasts.

Even though open defecation is a serious health threat, it should not be condemned categorically in areas with low population densities. Open defecation might be preferable to using poorly maintained latrines <sup>(57)</sup> which can become foci for the transmission of diarrhoea <sup>(40)</sup> and hookworm <sup>(9)</sup>.

### 6.2.2 Poor hygiene of sanitary structures

Sanitary structures can play an important role in disease transmission if they are not kept clean <sup>(28)</sup>. Faecal-oral infections can be spread through direct contact with faeces, contaminated material, or through flies or cockroaches. Latrines with floors contaminated with faeces can transmit hookworm.

Sanitary structures must be kept clean to reduce health risks and to make them acceptable to users. Installing a SanPlat, which is a smooth concrete latrine slab,



makes it easier to clean the latrine. A SanPlat can be built into a new latrine or an existing latrine can be upgraded <sup>(9)</sup>. The slab should slope towards the drop-hole so that spilled water, or water used for cleaning, flows into the hole. Figure 6.1 shows an example of a SanPlat.

## 6.2.3 Water supply and the sanitary structure

There should be a reliable source of water near the sanitary structure. Water is used for handwashing and cleaning the structure, and possibly for flushing or anal cleansing. The water does not have to be high quality as it is not used for drinking.

**Table 6.5. Water demands of a sanitary structure** <sup>(66)</sup>

<b>Water use</b>	<b>Quantity needed</b>
Handwashing	1-2 litres per person per day
Cleaning structure	2-8 litres per cubicle per day
Flushing (pour-flush)	3-5 litres per person per day
Flushing (sewerage)	20-40 litres per person per day
Anal cleansing	1-2 litres per person per day

Table 6.5 gives approximate quantities of water needed. A communal pour-flush latrine used by 20 people who use water for anal cleansing may need around 200 litres of water per day to work – and be used – correctly.

#### **6.2.4 Discharge of excreta or effluent in surface water**

Discharging excreta-related waste into freshwater causes different risks than discharging into seawater.

##### **Discharging excreta in freshwater**

Discharging excreta, nightsoil, or sewage into fresh surface water creates a serious health risk. Faecal-oral infections can be transmitted to people who drink the contaminated water, and water-based helminths (e.g. schistosomiasis, clonorchiasis) can infect their intermediate hosts. If cattle and pigs drink contaminated water, they can be infected with beef and pork tapeworm. Domestic flies, which transmit conjunctivitis and trachoma, and *Culex* mosquitoes, which transmit filariasis and several arboviral infections, can breed in surface water polluted with faeces.

The discharge of excreta, nightsoil, or raw sewage into fresh surface water should be limited as much as possible. The practise would only be acceptable where the waste was diluted in a large volume of moving water, where people are not in contact with the water (including people downstream), and where the risk from food taken from the river is very small. This combination is unlikely to occur in developing countries.

As conventional sewage treatment plants do not usually reduce the number of pathogens to a safe level (their main aim is generally to reduce the BOD to acceptable levels), their effluent is normally still very polluted. Exceptions to this are properly designed and functioning waste stabilisation ponds, plants with maturation ponds, and adequate filtration systems (see Section 6.2.6) <sup>(28)</sup>.



### **Discharging excreta into seawater**

Only faecal-oral infections pose a health risk if excreta, nightsoil or sewage are discharged into seawater. The cysts of protozoa and the eggs of helminths will settle out rapidly, so only viruses and bacteria will normally be a threat. It is unlikely that pathogens will travel more than a few kilometres from a sewage outfall.

As seawater is not used for drinking, the main health risk comes from handling or eating contaminated fish and shellfish. Fish can harbour pathogens in their body for weeks and can therefore be a risk if they are caught close to a sewage outfall. As shellfish can accumulate pathogens in their bodies, they are a larger health risk than fish. Fish and shellfish should always be properly cooked before eating.

The additional health risks from contaminated seawater will normally be limited if people already live in an environment with poor sanitation <sup>(28)</sup>.

### **6.2.5 Groundwater pollution by sanitary structures**

Polluted liquid seeping out of sanitary structures can sometimes percolate through the soil into the groundwater. The groundwater can thus be polluted with pathogens and chemicals from the excreta. Both types of pollution will be covered here, with the emphasis on pollution by pathogens.

Only faecal-oral pathogens will be transmitted by polluted groundwater, and unless the soil consists of fissured rock or coarse sands, only viruses and bacteria will pose a risk. Because of their large size, the cysts of protozoa and eggs of helminths will easily be blocked by the soil and will not seep down <sup>(42)</sup>.

Groundwater pollution will only be a problem if the groundwater is used for drinking, or if water mains with intermittent supply are piped through polluted soil (see Section 5.2.3).

It is important to remember that the health risks from open defecation or from using inadequate sanitary structures are usually greater than the health risk of polluting the groundwater by sanitation.

If groundwater pollution is a serious risk, it is usually more appropriate to change to a piped water supply than to install off-site sanitation (e.g. a sewerage system).

Although groundwater pollution is often used as an argument against on-site sanitation (e.g. pit latrines), poorly constructed or maintained sewerage systems are just as likely to pollute the groundwater <sup>(62)</sup>.

### **Pollution in the unsaturated zone**

In the zone above the water table, polluted liquid from the sanitary structure will percolate downwards under the influence of gravity. The removal of pathogens in the unsaturated zone is very effective <sup>(31)</sup>, and where groundwater pollution could be a problem, this distance should be maximised (e.g. by raising the latrine, using a shallow pit) <sup>(42)</sup>. If there is at least 2m of fine sand or loam between the source of pollution (e.g. the base of the pit of the latrine) and the groundwater table, most pathogens will be removed from the liquid <sup>(57)</sup>. Within months of a latrine being used an organic mat will form naturally in the soil. This mat is very effective in removing pathogens <sup>(42)</sup>.

### **Pollution in the saturated zone**

To understand the principles of pollution below the water table, the movement of groundwater in the saturated zone must be understood.

Shallow groundwater tables usually follow roughly the form of the terrain <sup>(34)</sup>. As water flows from high to low areas, groundwater will normally move in the same direction that water on the surface would flow. As a rough rule, the steeper the terrain and the coarser the soil particles (if there are no small particles like silt and clay), the faster the groundwater will flow <sup>(24)</sup>.

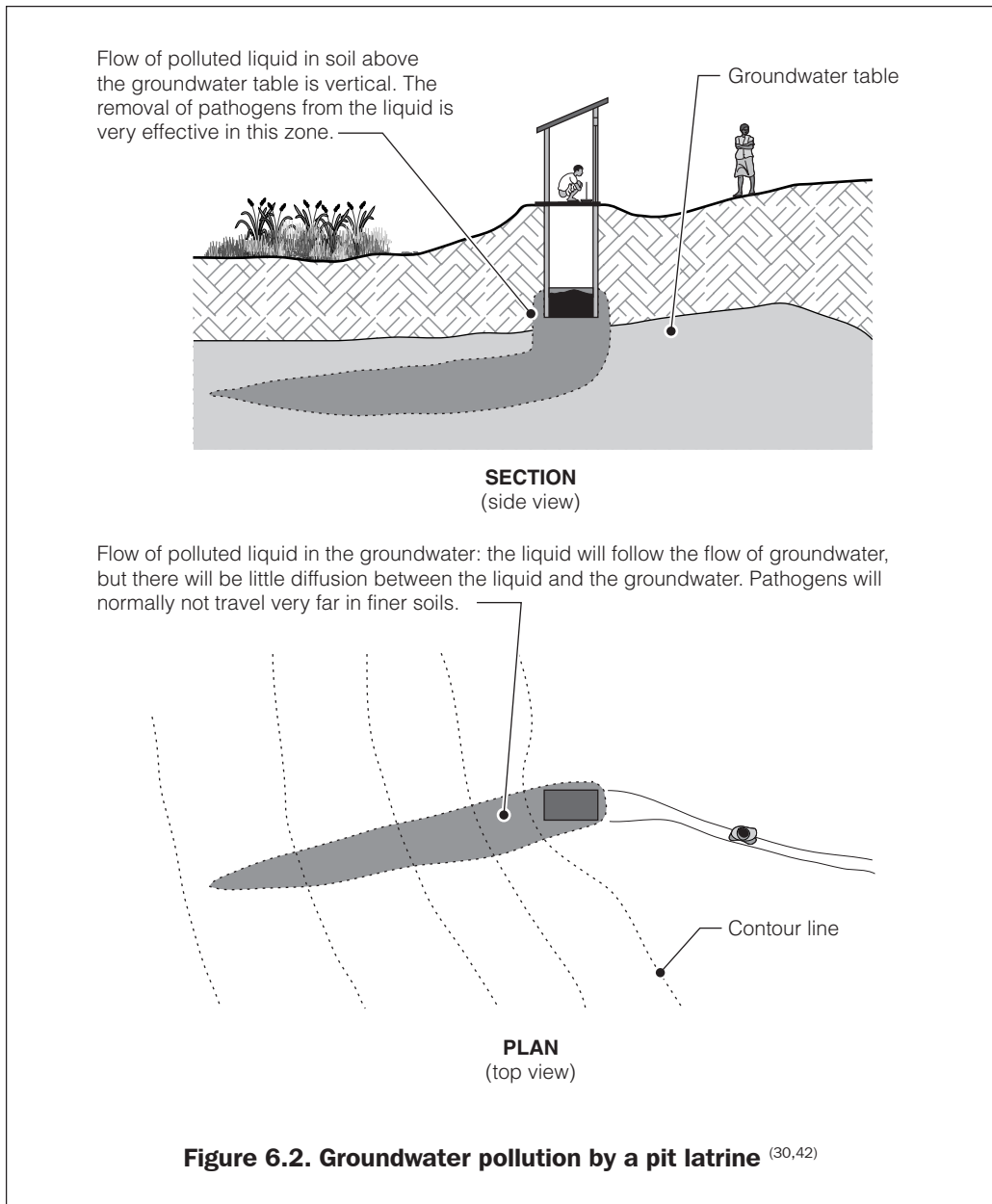
When the polluted liquid meets the groundwater, the liquid will be carried with the groundwater flow. The liquid forms a 'tongue' which follows the flow of the groundwater, but the liquid and the groundwater do not really mix <sup>(30)</sup>. This is shown in Figure 6.2.

Bacteria will not normally travel further than the distance the groundwater flows in 10 days <sup>(42)</sup>. Predicting the exact distance that pathogens will travel from a sanitary structure is difficult, as this will depend strongly on the local situation. In terrain with a low gradient and medium to fine sands, bacteria will probably not travel further than 10 metres. Viruses can travel further, as can bacteria in coarse sands or fissured rocks <sup>(42)</sup>. In fine soils a safety distance of 15 metres will usually be adequate <sup>(57)</sup>.

These values can be used for sanitary structures which have to deal with up to 50 litres of liquid per horizontal m<sup>2</sup> per day <sup>(30)</sup>, and family structures will usually not exceed this.

Even though pathogens are removed from the flow, they are not necessarily killed, and if large volumes of liquid are suddenly discharged, viable pathogens which were 'stuck' may be flushed out. Pathogens will not travel as far if the same amount of liquid is discharged continuously than if it is discharged in gushes.

## SANITATION



If groundwater is abstracted through a properly sealed borehole well below the polluted layer, the water from the pump will be safe. This only works if water is abstracted in low volumes (e.g. with a handpump). Mechanised pumping can draw down the water table to such an extent that the pollution of deeper groundwater is possible <sup>(24,57)</sup>. A properly sealed borehole that pierces an impermeable layer would be even safer. It might sometimes be possible to install latrines and

properly constructed tube-wells close together, but it is always better to have a minimum safe distance between the two.

### **Chemical pollution of groundwater through sanitation**

The chemical pollution of groundwater is caused mainly by nitrogen (nitrate) and chloride <sup>(43)</sup>. The health risk of chloride in groundwater is limited <sup>(46)</sup> (chloride is a component of kitchen salt), but a high chloride content could make the water taste unacceptably salty. Nitrate can cause blue-baby syndrome in infants, but this risk seems to be limited <sup>(62,68)</sup>. Nitrate is possibly linked to gastric cancer and congenital deformities, but here again, the risks seem to be limited <sup>(62)</sup>.

Unless there is a high population density, or some other cause of chemical pollution (e.g. using sanitary structures to discharge chemically polluted waste water), the health risk of chemical polluting groundwater by sanitary structures will usually be small.

### **6.2.6 Re-use of excreta**

Excreta can be a valuable resource. Excreta-related wastes can be used for:

- fertilising or irrigating crops: nightsoil, sludge, sewage or composted wastes can be used to fertilise plants, and sewage or effluent can be used for irrigation (and fertilisation).
- Aquaculture: nightsoil, sludge or sewage can be used to feed fish in ponds.
- Gas production: nightsoil is used to produce biogas, a useful source of energy.

Fresh excreta, nightsoil, sludge, sewage, or effluent can all contain large quantities of pathogens, and thus pose a serious health risk to the people who handle the waste and those around them. People who work directly with waste or who live or work close to where excreta-related wastes can all be at risk from excreta-related infections. But excreta, effluents, and sludge can be treated to make them relatively safe to handle and re-use.

### **Treatment of excreta-related wastes**

There are several ways to make excreta-related wastes safer. The waste may not be totally free of pathogens, but if one of the following techniques are used correctly, the risk of handling the treated waste will normally be negligible.

- Pass the waste through properly designed and working waste stabilisation ponds <sup>(15)</sup>.
- Let the effluent from a sewage treatment plant sit for enough time in maturation ponds.

- Filter sewage treatment plant's effluent through a sand bed.
- Compost excreta, nightsoil or sludge under aerobic conditions, at temperatures of at least 62°C for over one hour, 50°C for over one day, or 46°C for over one week.
- Treat nightsoil or sludge with heat; temperatures and duration should be at least equivalent to those mentioned above <sup>(28)</sup>. The high financial and environmental costs of fuel will usually make this method inappropriate.
- Bury excreta, nightsoil, or sludge for two years <sup>(30)</sup> (e.g. use twin-pit latrines, bury nightsoil or sludge in trenches, or top with earth full latrines). In tropical climates most pathogens, except for roundworm, will not survive longer than one year when buried.
- Dry nightsoil or excreta for at least one year <sup>(28)</sup>.

Fresh excreta, nightsoil, and any type of excreta-related sludge or effluent that has not been treated adequately can contain pathogens and should therefore be isolated as much as possible from people, animals, insects, food, crops, vegetables, soil, and water. Conventional sewage treatment plants usually do not reduce the number of pathogens to safe levels, and their effluent can still contain high levels of pathogens.

### **Use of excreta-related waste for fertilisation and irrigation**

The main health risks of workers (and often of their families) who use excreta-related waste for fertilisation or irrigation are faecal-oral infections and soil-transmitted helminths (e.g. roundworm and hookworm). Where workers come in contact with contaminated surface water schistosomiasis could also be a problem.

Consumers of the crops are at risk of faecal-oral infections and ingested soil-transmitted helminths (e.g. roundworm and whipworm).

The health risks of using excreta-related waste for fertiliser should be reduced by minimising the contact between crops and pollution as much as possible (e.g. through subsurface irrigation). Excreta-related wastes should only be applied before the crops are planted or up to one month before the crops are harvested. This will reduce, though not eliminate, the risks of faecal-oral pathogens. The health risks of soil-transmitted helminths will not be reduced significantly.

The health threat to people can be reduced by feeding these crops to animals, though several infections (e.g. salmonellosis and beef and pig tapeworm) will remain a health threat to people through infections in the animals <sup>(28)</sup>.

### **Use of excreta-related waste for aquaculture**

Using excreta-related waste to feed fish ponds creates several health risks. People who handle, prepare, or eat undercooked fish from these ponds are at risk from the faecal-oral pathogens that are on the fish's body or in its intestines <sup>(28)</sup>.

In addition to faecal-oral infections, consumers are at risk from water-based helminths which use fish as an intermediate host (e.g. clonorchiasis and opisthorchiasis). These pathogens can be transmitted to people or animals if the fish is not properly cooked. Other pathogens which have to reach surface water to develop (e.g. schistosomiasis) could also potentially be transmitted.

Keeping the live fish in unpolluted water for two to three weeks before eating them will reduce the health risks.

As the eggs of water-based helminths with two intermediate hosts settle out easily in water, the risk of these pathogens can be reduced by putting ponds in series, and only harvesting fish from ponds which have not been fed with excreta-related wastes <sup>(6)</sup>.

### **Production of biogas**

Handling excreta and the sludge that has to be removed regularly from a biogas plant could be a health risk. The sludge could be heavily contaminated with pathogens and should be handled and disposed of with the same care as fresh excreta.

### **6.2.7 Some practical issues on the planning and construction of sanitation**

While not all practical sanitation issues can be considered here, some important issues need to be highlighted.

#### **Assessment**

To maximise the impact of improved sanitation, everyone must have access to adequate structures, and these structures must be used correctly.

The structures have to be adapted to local behaviour, traditional beliefs, and the population's needs. In addition, sanitation has to be affordable to the users, and appropriate for local institutional capabilities and restrictions. The structures also have to be adapted to the physical situation in which they will have to operate. A thorough assessment will be needed, and it is likely that different groups will identify different issues, needs, and preferences, and these must be identified and

considered. It is especially important to address the problems of marginalised people to ensure that everyone has access to sanitation.

### **Household versus communal latrines**

Each household should normally have its own sanitary structure so that responsibility for maintenance and cleanliness lies with the family.

In a stable situation, communal latrines should only be considered if it is impossible to install structures at household level (e.g. because there is no space or installation is unaffordable), or in public structures like schools or hospitals.

Where communal structures have to be installed, the issues of management, cleaning, maintenance, and operation must be worked out before construction begins. Usually people have to be employed to keep communal structures clean<sup>(56)</sup>. The facilities for men and women should be separated, and issues of privacy and safety for women using the structures, or walking to the structures, have to be addressed in the planning phase.

### **Numbers and location of latrines**

People will only use sanitary structures if they do not lose too much time at them. This is achieved by having enough latrines available and siting them close to the users.

There should be no more than six cubicles per communal latrine<sup>(21)</sup>, with not more than 20<sup>(66)</sup> or at most 25 users per cubicle<sup>(21)</sup>. Structures should be sited less than 50 metres<sup>(66)</sup> from people's houses, and at most 250 metres<sup>(21)</sup>.

If groundwater is the community's drinking-water source, latrines must be located and constructed so that the risk of contaminating groundwater is minimal. As a general rule, if the latrine is constructed in fine soils, there should be at least 15 metres between the water source and the latrine. If possible, the water source should be installed on higher ground than the latrine. Where the soil is coarse, or waste water is discharged in the structure, the distances between water source and latrine may have to be more. (The problem of groundwater pollution has been addressed in more detail in Section 6.2.5.) Latrines should be located so that the risk of flooding by stormwater or floodwater is minimised. The top of the latrine slab should be raised a minimum of 0.15 metres above surface level to prevent surface water or rainwater from entering the structure<sup>(30)</sup>. Pits should be dug some metres away from the foundations of buildings as this could weaken the foundation or cause collapse; and pits must not be dug against a road carrying heavy traffic as this can also collapse the pit.

### **Sanitation in emergencies**

In the early stages of an emergency it is not usually feasible to provide household latrines or even enough communal latrines. It may be necessary to construct structures with 50 to 100 users per cubicle or metre of trench (if trench latrines are used) to begin with. This must be upgraded as soon as possible to communal latrines with 20 users per cubicle, or household latrines <sup>(47)</sup>. As it is not normally possible to provide adequate structures from the beginning, and the aim should be to decrease the health risks and increase the convenience to the users as quickly as possible.

Start by discouraging people from defecating near any water source used by people and animals, or in fields where crops for consumption are grown. As soon as possible defecation should be confined to specific areas: open defecation fields or trench defecation fields. The next step could be to install trench latrines, or communal borehole or pit latrines. Following that latrines could be installed at household level if feasible <sup>(64)</sup>. Provision should progress through these steps as soon as possible, to use the best feasible structures at all times.

If communal latrines are installed people have to be employed to maintain and clean them. Anal cleansing material, water and soap for handwashing, and soil to cover the excreta may have to be provided <sup>(66)</sup>.

If insects can access the contents of the latrines, the excreta should be covered with 0.1 metre of soil every two to three days <sup>(21)</sup>.

### **Some issues concerning construction**

Structures are designed to last a certain period (the 'design life'). In a stable situation the pit of a latrine may be expected to last for up to 30 years <sup>(30)</sup>. The expected number of users at the end of the design life should be used when designing structures. Annexe 5 has information on the accumulation rates of solids in pit latrines, and how to estimate the infiltration capacity of the soil.

Where soil stability, soil erosion, or rats could become a problem, the top 0.5 metres of a pit should be protected with a closed lining. If the soil cannot carry much weight the superstructure should be light. It may be necessary to make a foundation in the form of a concrete ring beam to make the latrine structurally sound <sup>(30)</sup>. The more complex a latrine becomes, the more expensive and demanding its construction will be.

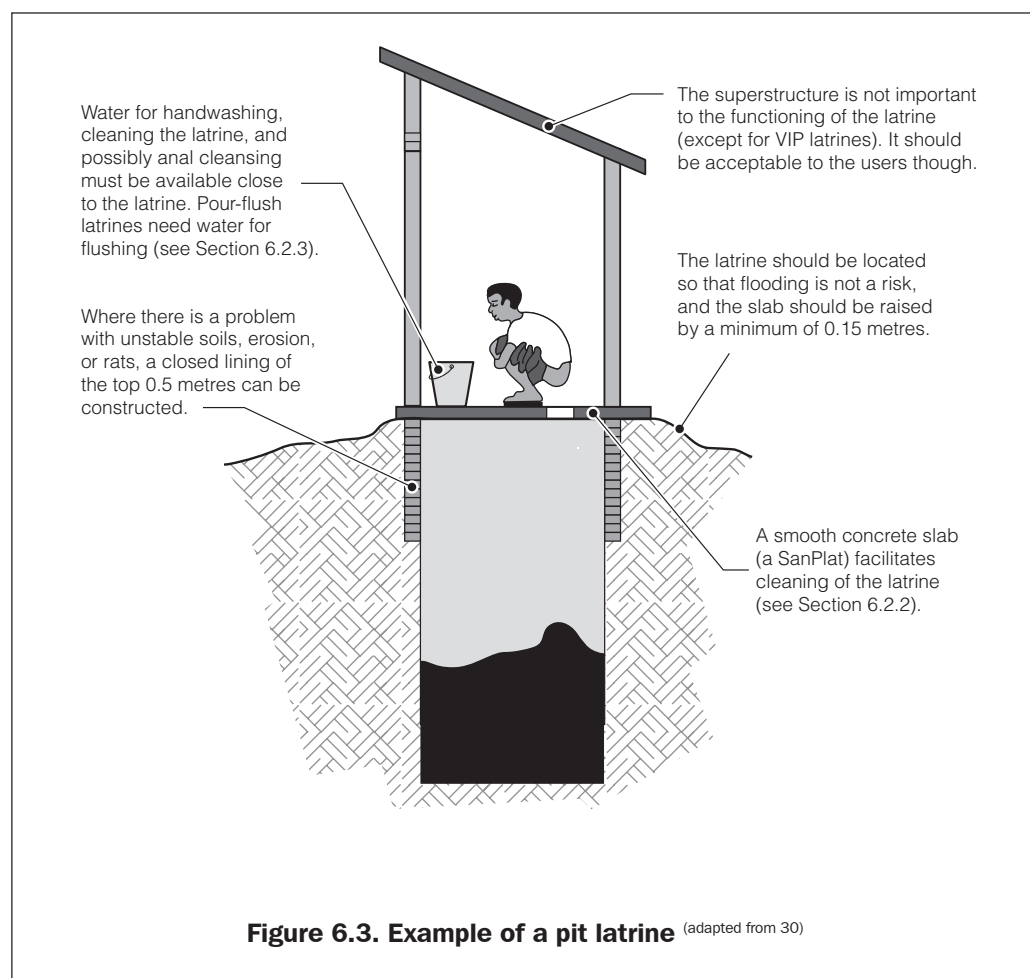
Latrines should be built so that insects cannot enter the pit. This can be achieved by installing a tight-fitting lid (this is difficult in a communal structure), a water



seal (this will only be adequate if water or soft paper is used for anal cleansing), or a VIP-latrine (this type of latrine is probably less adapted to use at household level as they are expensive and rather complex; in addition, VIP latrines usually do not stop mosquito breeding). If the latrine is 'wet', polystyrene beads can be used to create a floating layer which will prevent mosquitoes from breeding in the pit <sup>(61)</sup>. All other openings which give access to the pit containing excreta should either be sealed or closed with flyproof netting.

Vandalism and theft must be prevented by sealing the lids of access-holes with mortar or locking them and by making structures as solid as possible; this is especially important in communal structures.

This example of a pit latrine (Figure 6.3) shows some of most important points for proper use.



## Chapter 7

### Drainage

This chapter looks at the health risks caused by the presence of water<sup>1</sup> in the human environment and how this water can be drained. The purpose of drainage is to remove unwanted water from the human environment <sup>(17)</sup>. It is often difficult to make a clear separation between ‘unwanted’ and ‘wanted’ water, as people will usually use surface water, for example for irrigation or watering animals. What is unwanted, however, are the health risks associated with surface water.

From a health point of view, the properties of the surface water are usually more important than its origin. The WES specialist needs to separate the different sources, as different types of structure will be needed to deal with them properly. In the section on surface water and the transmission of disease we will look generally at surface water, while in the section on the practical aspects of drainage we focus on the sources of water and how to cope with them.

Drainage must handle water of different origins: domestic waste water (or sullage), rainwater (or stormwater, runoff), floodwater, and water from natural sources (e.g. springs).

**Sullage** includes used water (e.g. washing water), water spilled at the distribution point, water from leaks in the system, or from taps. Sullage is usually produced in low volumes, and without seasonal fluctuations.

**Stormwater** is that rainwater that has not infiltrated into the soil, was not intercepted by the vegetation, and did not evaporate. This surplus water will either collect in depressions in the surface, or flow over the surface until it reaches channels, streams, or rivers, through which it will be evacuated. Stormwater often occurs in large volumes, and is a seasonal problem.

**Floodwater** is generally water from overflowing rivers or channels. Flooding is a seasonal problem which usually involves large volumes of water <sup>(15)</sup>.

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<sup>1</sup> The health risks associated with water in the human environment are normally caused by fresh surface water

**Natural water sources** can result in unwanted water if the water is able to collect in large puddles or ponds.

In addition, industry, agriculture, mining, and other activities (e.g. medical facilities, abattoirs) may produce waste water. Most of the health risks related to these will be similar to the other types of surface water, but there may be specific health risks related to these types of waste water. These specific health risks are not covered by this manual.

Surface water can exist in many types of reservoirs. Naturally occurring surface water is found in lakes, marshes, natural ponds, streams, rivers, puddles – even leaf axils collecting rainwater can form ‘reservoirs’. Artificial reservoirs of surface water include irrigation systems, channels, artificial water reservoirs (e.g. for hydroelectric power generation), overhead tanks, swimming pools, and pits resulting from construction work, agriculture, mining, brickmaking or other activities. Even small ‘vessels’ like old tyres, drums, blocked roof gutters, empty plant pots, or old cans that accumulate (rain)water may serve as a reservoir for ‘surface water’.

### **Issues concerning drainage other than health**

Stormwater, or floodwater, can kill people or animals, and can destroy buildings, roads or crops. Floods can make it impossible for people to move around. Poor drainage can cause landslides and mudflows, which may be a risk to people and their property. Stormwater can erode fertile soil, reducing production.

On the other hand improved drainage may degrade the environment if natural wetlands or ponds dry out or are filled in, if the local water-balance is disturbed, or if organically polluted drainage water is discharged into surface water, using up all its oxygen.

Artificial reservoirs are built to benefit people, for example by providing electricity or water for irrigation. In addition dams may benefit people downstream, as the flow of rivers or streams can be regulated, reducing the risks of floods or draughts. On the down side, people are often displaced and land and property lost when large artificial reservoirs are created. A dam may become a problem if people – or nature – are deprived of the water they depend on. If a dam bursts, a dangerous situation is likely to result.

## 7.1 Surface water and the transmission of disease

Drainage channels are frequently used for defecating, and the first rains after a dry period will often wash human and animal excreta from the surface into the drainage system. Water used for washing (people or clothes) will often contain faecal pathogens. Sullage or stormwater can therefore transmit faecal-oral infections directly to people and animals. If cattle and pigs can get to the water, they may become infected with beef and pork tapeworm. The chance of direct contact is increased if water stagnates in the drainage system because of blockages caused by soil, refuse, vegetation, or poor design or construction of the system.

If sullage or stormwater is discharged into fresh surface water (e.g. streams, rivers, lakes), the surface water will be polluted with excreta. This will result in a risk of faecal-oral infections and beef and pork tapeworm if people and animals use this water as drinking-water.

Any type of fresh surface water which is contaminated with urine or faeces can become a transmission risk for schistosomiasis. As the pathogen multiply in snails, even a light contamination of the water can create a large potential for transmission. Only fast-flowing rivers and streams, and deep water at a good distance from the shores, will be relatively safe <sup>(15)</sup>. Schistosomiasis is often associated with irrigation schemes and artificial reservoirs <sup>(36)</sup>.

In addition to schistosomiasis, water-based helminths with two intermediate hosts can benefit from the discharge of faecally polluted drainage water into surface water.

Temporary pools and small containers (e.g. cans, drums, blocked gutters) full of relatively clean water are potential breeding sites for the *Aedes* mosquitoes which transmit filariasis, yellow fever, dengue fever, and several other arboviruses. The eggs of *Aedes* mosquitoes can survive for months outside the water, but must be in the water to hatch.

Where organically polluted water can accumulate (e.g. stagnant water polluted with waste from sanitary structures, organic refuse, or rotting plants), *Culex* mosquitoes, which transmit filariasis and several arboviral infections, can breed. *Culex quinquefasciatus* is often a problem in urban areas.

Where ponds or puddles of relatively clean water form, preferably with some form of vegetation, *Anopheles* mosquitoes, vectors of malaria and filariasis, can breed. *Anopheles* mosquitoes also breed in lakes, rice fields, and calm areas in slow

streams <sup>(61)</sup>. Malaria is a problem associated with the presence of artificial reservoirs <sup>(6)</sup>.

Surface water does not need to be permanent to be a risk; mosquitoes and snails can breed and survive in temporary or seasonal puddles and ponds. Mosquitoes can develop from egg to adult in less than two weeks <sup>(80)</sup>. Snails transmitting schistosomiasis can survive in ponds that dry up seasonally <sup>(5)</sup>, and one snail can grow out into an infectious colony within two months <sup>(73)</sup>.

A number of other infections could be a risk where drainage is poor.

If drainage water comes in contact with soil, it can become contaminated with soil-transmitted helminths (e.g. hookworm disease, roundworm infection). The soil-transmitted helminths need moist soil in which to breed, an environment which can be created by inadequate drainage. Sandflies, the vector of leishmaniasis, Bartonellosis and several arboviruses, breed in humid, organic soils <sup>(61)</sup>.

Polluted water (e.g. from stagnant water in drainage channels) is a potential breeding site for the domestic fly <sup>(21)</sup>, which can transmit faecal-oral diseases and infections transmitted by direct contact.

Rats are attracted to surface water, and can be a host for a multitude of infections including plague <sup>(80)</sup>.

Turbulent, shallow ‘white water’, which can be created in the spillways of reservoirs, can become a breeding site for blackflies, which can transmit river blindness <sup>(6,15)</sup>.

Table 7.1 presents the infections related to poor drainage.

### **The health risks of seawater and brackish water**

The health risks linked to surface water are mainly related to freshwater.

The health threat of seawater is limited. The chance of transmitting excreta-related pathogens by seawater is small (see Section 6.2.4), and vectors and intermediate hosts can not survive in seawater.

Depending on the water’s salt content, the chances of excreta-related pathogens surviving or being transmitted will be higher in brackish water (water with a salt content between that of seawater and freshwater) than in seawater.

**Table 7.1. Disease categories associated with poor or absent drainage**

Risk-factors related to drainage		Disease categories								
		Faecal-oral infections	Schistosomiasis	Water-based with two intermediate hosts	Soil-transmitted helminths	Beef and pork tapeworm	Leptospirosis	Guinea-worm infection	Spread by direct contact	Vector-borne infections
i	Water accumulates									
ii	The drainage functions poorly, or is badly designed									
i	Clean surface water	(a)				(b)			(c)	
	Organically polluted surface water	(d)				(b)		(d)	(e)	
	Resulting in moist soil								(f)	
ii	Stagnant water in drainage					(b)		(d)	(e)	
	Poor disposal of drainage water					(b)		(d)	(e)	

(a): as long as some food (plants, organic matter) is present in the water

(b): through rats being attracted to, and contaminating, the surface water

(c): *Anopheles* and *Aedes* mosquitoes

(d): through domestic flies

(e): *Culex* mosquitoes

(f): sandflies

Although most mosquitoes do not like salt water, some can breed in slightly salty water. *Anopheles* mosquitoes are in general more sensitive to salt water than *Culex* and *Aedes* mosquitoes <sup>(77)</sup>. Some species of *Aedes* mosquitoes are able to breed in coastal salt marshes <sup>(61)</sup>.

## 7.2 Practical issues concerning drainage

This section looks at some practical issues concerning the drainage of sullage and stormwater, and how other sources of surface water can be dealt with. Issues concerning flooding by external water bodies or large artificial reservoirs are not covered as they are complex, and will not normally be dealt with by a WES specialist at field level.

### 7.2.1 The disposal of sullage

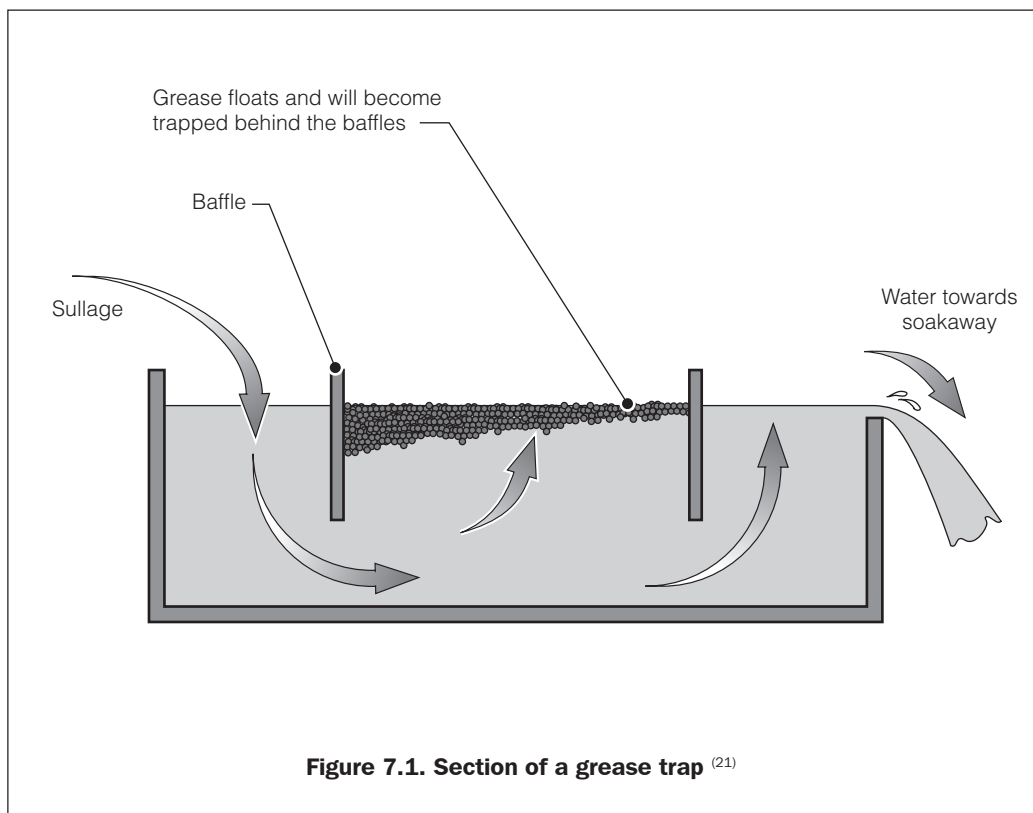
Domestic waste water can often be disposed of where it is ‘produced’ (on-site disposal).

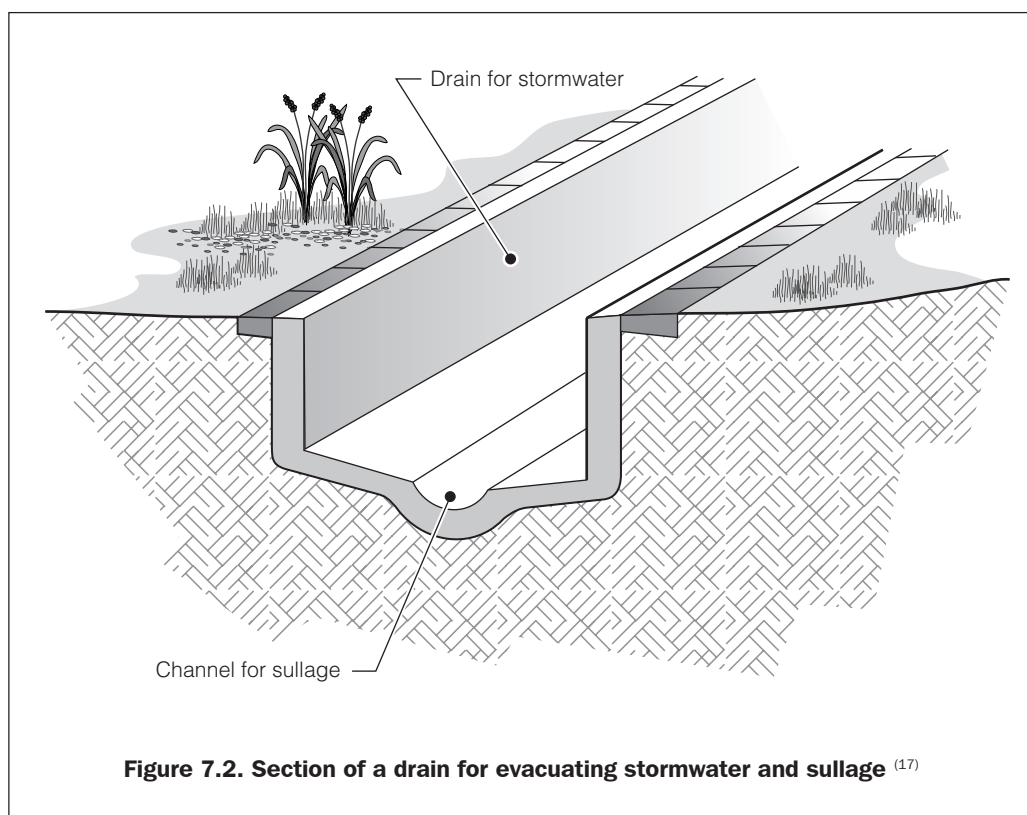
## DRAINAGE

Where waste water is not polluted with pathogens (e.g. water spilt at a hand-dug well or handpump), it can be fed directly into a garden or vegetation. Care should be taken that no ponding can occur.

Soakaway pits and trenches can be used where waste water could be polluted, space is available, and the infiltration capacity of the soil is sufficient. A soakaway will have to be adapted to the physical situation and the characteristics of the sullage to prevent blockage or overloading.

The infiltration surface area ('surface of infiltration') must be adapted to the amount of waste water discharged and the infiltration capacity of the soil. Sand can be assumed to have an infiltration capacity of around 200 litres per m<sup>2</sup> per day. Silt and loam will normally be able to deal with up to 100 litres per m<sup>2</sup> per day. The infiltration capacity of clay will normally be less than 50 litres per m<sup>2</sup> per day. These values are for soil above the groundwater table <sup>(57)</sup>. It must be assumed that the pores in the bottom of the pit will clog with settled material, so only the vertical sides of the pit are used to calculate the surface of infiltration. If a lining is used, only the surface of the bare soil should be considered.





Where sullage contains solids, they should be removed by straining the waste water or feeding it through a silt trap (i.e. a small reservoir which allows the solids to settle) . If the waste water contains grease or soap, a grease trap will have to be installed. Silt and grease traps should be impenetrable to insects and rats cannot enter. Figure 7.1 shows a model of a grease trap. Regular maintenance is necessary to ensure that these structure function properly.

Where enough surface is available and the climate is appropriate, evaporation pans or beds can be used. Eliminating waste water through evaporation is only possible where the climate is hot, dry, and receives very little rain throughout the year. Wind increases evaporation. Even in these ideal circumstances large surfaces are needed; open water will evaporate 5 to 10 litres per m<sup>2</sup> per day, an evaporation bed with vegetation can probably evaporate around 2 litres per m<sup>2</sup> per day <sup>(21)</sup>.

Where the population density is high or the soil relatively impermeable, on-site disposal may not be possible. If there is a sewage system sullage can normally be discharged this way. If on-site disposal and sewerage are not present or possible, it may be necessary to dispose of the waste water in drains. Figure 7.2 shows a drain



which can dispose of sullage as well as stormwater. The small channel in the drain is to discharge sullage, and its rounded form allows small amounts of water to flow at sufficient velocity to keep solids in suspension. This practise is not ideal as people, animals, and insects can come into direct contact with the waste water, but it is better than allowing waste water to pond. The health risks of discharging the waste water will have to be assessed, and if necessary, reduced.

Before considering using existing structures (e.g. pit latrines) for disposing of waste water, investigate whether the existing structure can cope with the quantity of waste water that is to be discharged. Up to 80 per cent of the water supplied to users may become sullage <sup>(17)</sup>.

Annexe 5 can be used to estimate the infiltration capacity of an existing pit already used for excreta. Discharging more liquid into the pit will also increase the distance that pathogens from the excreta in the soil will travel.

### **7.2.2 The drainage of stormwater**

Where stormwater poses a risk to people, animals, or structures, or where it could pond and thus become a health risk, a drainage system will be needed to collect the stormwater and lead it away safely.

The size, type, and finish of the drainage system will depend on the availability of funds and the potential damage a flood could cause. The greater the risk, the greater the amount that should be invested in preventing flooding. Drainage systems need to be designed in combination with other structures (e.g. roads, buildings) to adapt the structures to one another.

In Annexe 6 a method is presented to calculate how much water would be discharged from a catchment area, and the size of the drain needed to discharge this amount of water. This method can be used to design a simple drainage system, or assess whether a proposed design is realistic. The design of a more complex system will be more demanding, and if the reader is not familiar with these procedures the design should be left to a specialist.

Refuse, soil, and the vegetation which accumulates in drainage channels will reduce the capacity of the system, and regular maintenance will be needed to keep it functional. Regular maintenance and inspection will also deal with collapse or other structural damage in the system.

The responsibilities of all actors in maintenance and structural repairs must be addressed early in the planning phase. Drainage systems are usually communal,

but the basic maintenance of the system at neighbourhood level (e.g. removing blockages, cleaning the channels) is probably best done at household level <sup>(17)</sup>. The problem of solid waste management should be addressed in the planning phase of the drainage system as poor management of refuse (e.g. domestic waste or waste from construction) will result in inappropriate waste ending up in the drainage system.

Where the channels are not protected with a lining, erosion can be a problem if water flows at high speed or if the sides of the drains are too steep.

If tools or other materials are required for maintenance, these must be available to those who need them.

### **7.2.3 Other types of surface water**

Temporary ponds or unwanted reservoirs can be filled to reduce the health risks. No new ponds should be created when sourcing the filling material. Where filling is not feasible, the vegetation along the sides of the water can be removed to make it less attractive to snails and mosquitoes, or the shoreline can be made steeper to control the vegetation.

The best way to deal with potential breeding sites for *Aedes* mosquitoes depends on the situation: solid waste must be removed, water tanks and drums must be covered with a lid or mosquito-proof netting, gutters should be maintained, hollow construction blocks or bricks should be filled, containers that are needed but not used should be turned upside down, and holes in trees must be filled <sup>(61)</sup>. It will only be possible to control *Aedes* by teaching people to be very vigilant and attentive to the problem.

Where springs result in ponding they can be protected (see Figure 5.3) to reduce the health risks.

## Chapter 8

### **Solid waste management**

Solid waste management is about dealing with refuse. This chapter looks at communicable disease in relation to solid waste, and presents some practical issues about managing refuse. Solid waste management up to neighbourhood level, including local health structures, is considered, but the management of wastes from industries, mining, or structures like large hospitals or abattoirs are more specialised, and will not be covered here.

Poor solid waste management will result in an unpleasant and often unsafe environment to live or work in. In addition, piles of refuse can be a fire hazard <sup>(15)</sup>.

In urban areas refuse often ends up in drainage systems, creating drainage problems (see Chapter 7).

Pollution caused by poor management of waste can create serious environmental problems. For example, one litre of diesel can in theory make around 80,000m<sup>3</sup> of water undrinkable according to European standards <sup>(46)</sup>.

#### **8.1 Solid waste management and infectious disease**

Solid waste is often contaminated with human or animal excreta. Those who handle the waste, and those who live or work where the waste accumulates, will therefore often be at risk from excreta-related infections. The specific health risks they will be exposed to will depend on their contact with the excreta (see Table 6.1).

As drainage systems are frequently used for defecation, the solid waste that accumulates in the system is often contaminated, and is a health risk to those who have to handle it <sup>(39)</sup>. (For the health risks related to blocked drainage systems see Chapter 7.)

Organic waste from households, restaurants, and markets attracts rats, which are potential hosts for many infections (e.g. leptospirosis, plague). Organic waste also serves as food and a place to rest and hide for domestic flies, which can transmit faecal-oral infections and infections spread by direct contact, and cockroaches, which can transmit faecal-oral infections.

Other animals which use refuse dumps to rest and hide include mosquitoes; sandflies, vector of leishmaniasis, bartonellosis, and several arboviruses; and reduviid bugs, which can transmit American trypanosomiasis <sup>(61,80)</sup>.

Refuse often includes materials which can collect rainwater, such as tin cans, jars, and old car tyres. *Aedes* mosquitoes, which transmit filariasis, urban yellow fever, dengue fever, and several other arboviral infections, can breed in these small water-filled vessels <sup>(67)</sup>.

Poorly managed waste often ends up in ponds, reservoirs, or drainage systems. The refuse often blocks drainage channels, resulting in the ponding of water. As these surface waters are often polluted with organic waste, breeding sites for *Culex* mosquitoes and domestic flies are created <sup>(21,61)</sup>.

Table 8.1 summarises the health risks relating to poor solid waste management.

## 8.2 Practical issues about solid waste management

A solid waste management scheme can be a large, complex, and expensive enterprise, with many people, materials, and funds required for good operation. Although it is not possible to go into much detail on solid waste management here, we will look at some important issues.

It is not always necessary to collect waste. In rural areas much of the refuse is re-used (e.g. feed for animals, containers, toys) and solid waste will often be less of a problem. In high-density (peri-) urban areas, however, waste may become a serious problem if poorly managed.

If on-site burial or burning are not possible, waste has to be collected. If affordable, household bins will usually be the most appropriate way of collecting and storing household wastes. Where this is not feasible, communal storage of the waste will be necessary. Collection points must be convenient if they are to be used, and their location must be chosen in collaboration with users. The structures should be designed and built so that insects, rats, and rainwater are kept out, and so that people are discouraged from using them for defecation. The emptying and maintenance of the structures by workers must be made as easy as possible.

## SOLID WASTE MANAGEMENT

**Table 8.1. Disease groups where poor solid waste management plays a role in transmission** (adapted from 60)

Risk factors of poor solid waste management:											
		Faecal-oral infections	Schistosomiasis	Water-based with two intermediate hosts	Soil-transmitted helminths	Beef and pork tapeworm	Leptospirosis	Guinea-worm infection	Spread by direct contact	Vector-borne infections	
i	Rats								(a)		
	Domestic flies/cockroaches										
ii	Refuse accumulates	(b)						(b)	(c)		
	Containers in refuse								(d)		
	Refuse blocks drainage				(e)			(b)	(f)		
III	Organic waste in water	(b)						(b)	(f)		
	Excreta in refuse										

(a): Flea-borne infections (plague, murine typhus fever)

(b): The risk is caused by domestic flies

(c): Vectors use refuse as a hiding/resting place: mosquitoes, sandflies, reduviid bug

(d): *Aedes* mosquitoes

(e): For humans: cysticercosis; for cattle and pork: beef and pork tapeworm

(f): *Culex* mosquitoes

The collection points have to be managed correctly, otherwise they will become a health threat. Regular collection is essential. In hot climates flies and rats can be attracted to solid waste within two days, so the refuse probably needs to be collected daily or every other day <sup>(17,21)</sup>.

Waste is often dumped in public areas or on wastelands. The uncontrolled discharge of waste must be discouraged, and the displaced wastes have to be collected. Part of solid waste management is making sure that refuse does not end up in drainage systems or surface water. The actual volume of wastes produced will depend on the situation. In low-income urban communities in developing countries one should count on a volume of 1 to 2.5 litres per person per day, with a weight of up to 1kg per person per day <sup>(15,17)</sup>.

In developing countries burying the refuse will usually be the most practical way of disposal. To prevent animals from accessing the refuse, it should be covered daily with 0.15m of soil. The last layer of soil covering the waste should be at least 0.5m thick <sup>(253,350)</sup>. Incineration is usually not feasible because of the frequently high content of moist (organic) waste, which would use too much fuel to burn.

### **Disposal of medical wastes**

In addition to 'normal' wastes, health centres, feeding centres, and specialised medical centres (e.g. cholera treatment centres) will produce medical waste.

There are different types of medical waste: sharp objects (e.g. needles, syringes, blades), material which has been in contact with blood, puss, or other body fluids (e.g. bandages or cotton wool), and organic waste (e.g. placentas).

There are many infections which could be transmitted through these wastes, and it is therefore important that they are disposed of so that the pathogens are isolated from people or animals.

Sharp objects should be collected in sturdy, closed containers with a small opening just large enough to pass the objects through. When these containers are full they should be discarded in a waste disposal pit. A disposal pit for medical wastes should be deep, with a superstructure with a small opening that can be locked securely. The superstructure must keep people, animals, insects, and surface water out. The pit is quite similar to a pit latrine.

Contaminated bandages and other materials should be wrapped in plastic bags reserved for and identified as medical waste. The bags should be burnt in an incinerator. It should be assumed that incinerated waste is still infective, and the ashes must be disposed of in the waste disposal pit <sup>(21)</sup>.

It will be difficult to incinerate organic wastes, so these wastes should be wrapped in plastic bags and thrown into the waste disposal pit.

To make sure the medical waste is properly dealt with, and to ensure that scavengers (e.g. children, animals) do not have access to it, the waste should not leave the compound of the health structures. The incinerator and waste disposal pit should be near each other, and should be fenced off to keep people and animals away.

Although the medical waste disposal pit is similar to a pit latrine, latrines should not be used for medical wastes as there is a risk of contaminating the slab or superstructure.

Whether normal waste from the health structure can be disposed of without special precautions will depend on how well the medical and uncontaminated waste are separated. If there is any doubt, all normal waste should be treated as medical waste and incinerated.

People dealing with waste in a health centre must be aware of the health risks, and be provided with protective clothing and adequate tools.

### **Disposal of the dead**

The health risk of a dead body is usually negligible, and the risk of an outbreak due to the presence of dead bodies after a disaster is extremely small <sup>(66)</sup>. Although rapid disposal of the dead is normally not necessary for health reasons, it may be demanded by the people, and this demand will have to be considered.

The exceptions are people who die during outbreaks of cholera, louse-borne typhus, or plague <sup>(21)</sup>. The dead bodies of people who die during these epidemics should be handled carefully. The bodies (and clothes) should be disinfected or treated rapidly; and the bodies should be manipulated as little as possible before burial or cremation.

