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 considermortality 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 [(41)]. With poliomyelitis, for example, if 80 to 85 per cent of the entire population is immune, the virus will disappear [(50)]. 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).

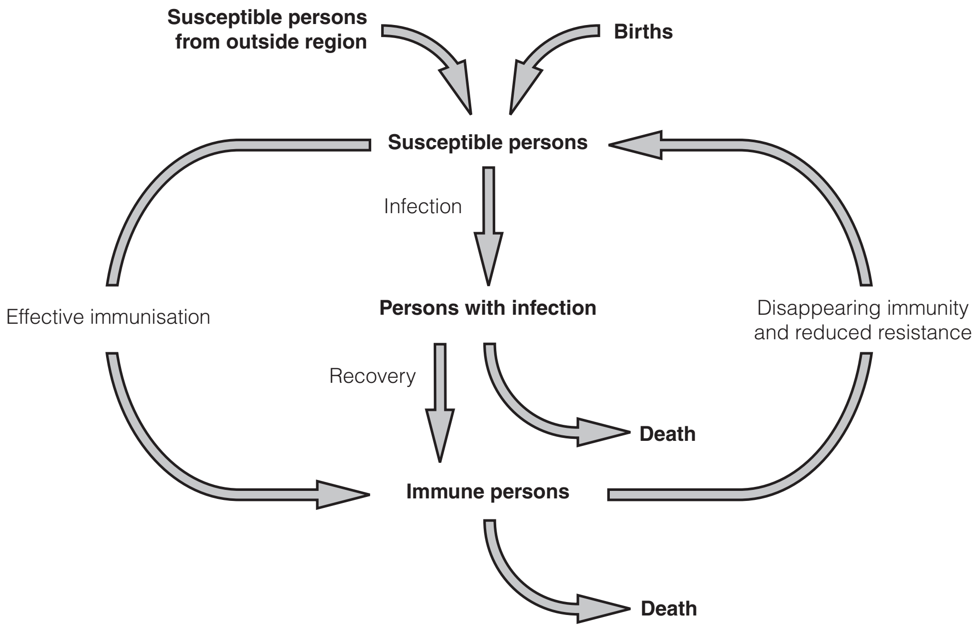


**Figure 3.1. Model of immunity in a population** (adapted from 37)

## 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 [(51)].

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

### 3.1.1 Endemic occurrence of disease

An infection is endemic when it is always present in a population [(3)]. 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 [(3)].

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) [(16)]; the poor may be more at risk because of the conditions in which they live (e.g. poor housing resulting in Chagas disease [73]); 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 [71].

Outbreaks can occur if the following features are combined [10]:

- 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 [79]);
- 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 [73]); 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 [10].

The most severe epidemics are those caused by infections which are easily transmitted, have short incubation periods [71], and have a potentially severe outcome. The main iInfections 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.

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 (10). 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 (55). 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 (10)**

| *Infection* | *In a non-endemic population* | *In an endemic population* |
|---|---|---|
| Salmonellosis | A group of cases with one common source of infection. | |
| Cholera | One locally infected confirmed case [a] | 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' |

[a] 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 [54]. 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 [71]:

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 [3]).

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) [71]?

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 [8]. 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 [55]. 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 [71].

### 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 [55]. 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 [73].

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 [3], 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.

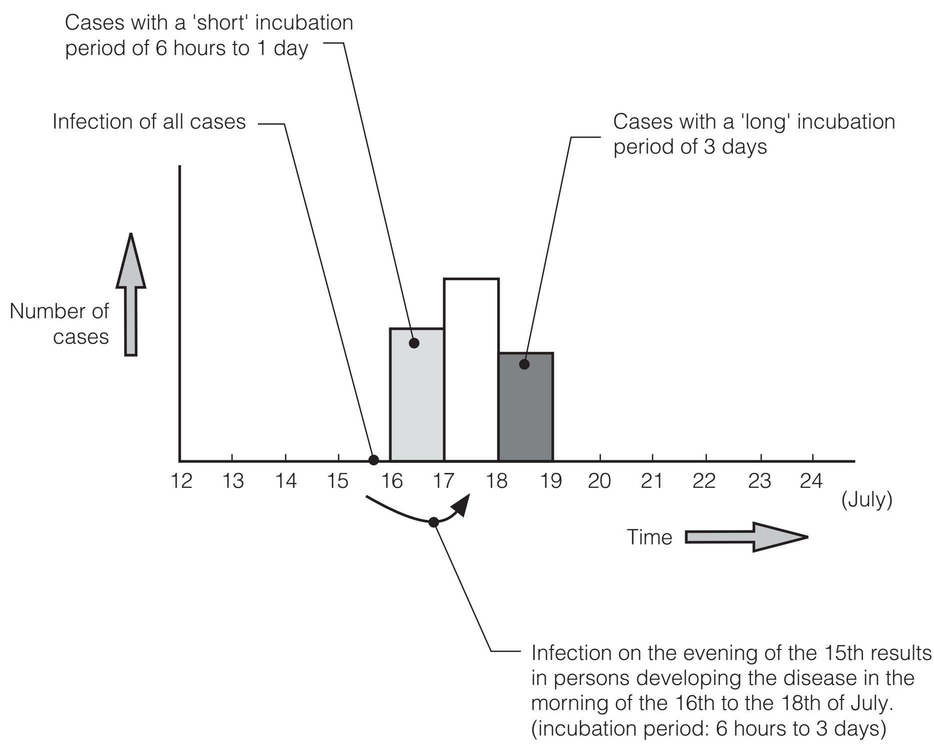


**Figure 3.2. The epidemic incidence curve of a point-source outbreak of salmonellosis**

## 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 (71). 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 (73).

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

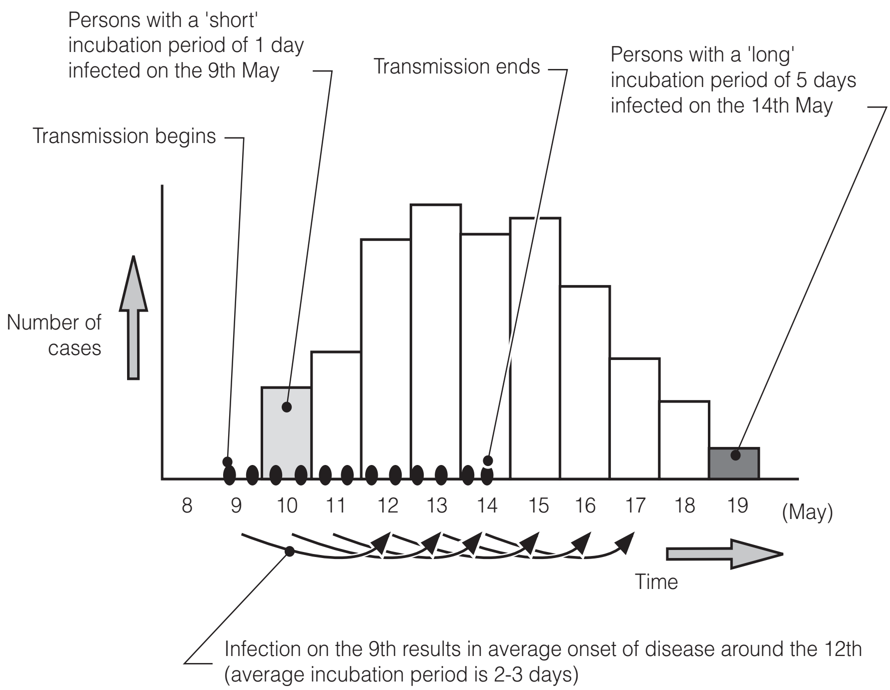


**Figure 3.3. The epidemic incidence curve of an extended point-source outbreak of cholera**

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' [73]. 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 [55,71].

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.

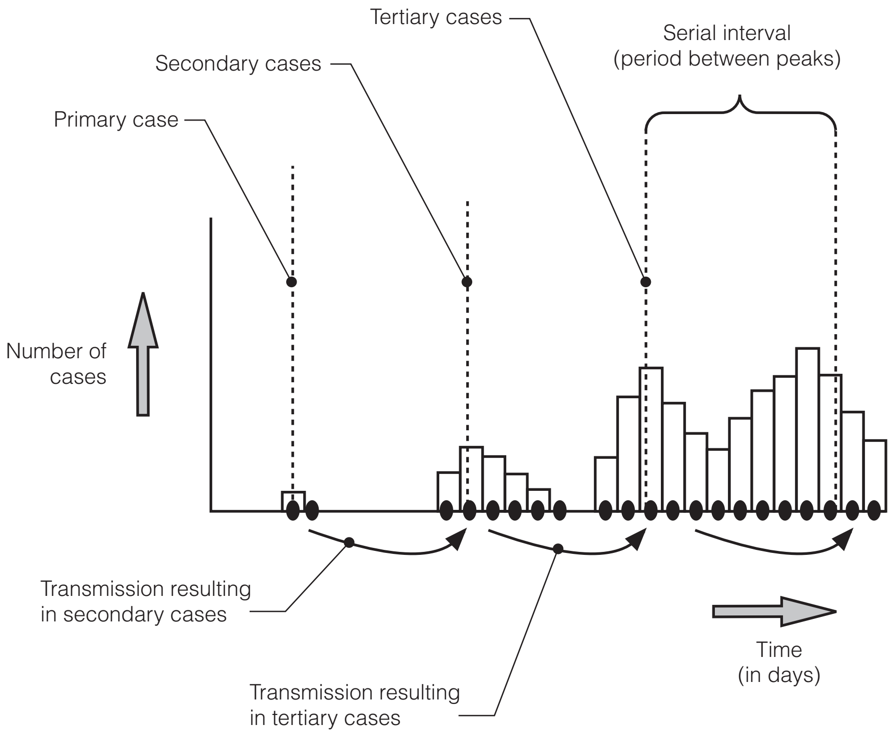


**Figure 3.4. The epidemic incidence curve of a propagated-source outbreak**

- 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) [71];

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**

| | *Situation* | *Mortality rates* |
|---|---|---|
| **Crude Mortality Rate (CMR)** | Developed communities | 10 deaths/1,000/year [71]<br>(0.3 deaths/10,000/day) |
| | Poor communities | 18-25 deaths/1,000/year [11,47]<br>(± 0.6 deaths/10,000/day) |
| **Infant Mortality Rate (IMR)** | Poor communities | 60-150 inf.deaths/1,000births/year [71]<br>(± 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 [47]. Mortality rates in the initial phases of an emergency can be much higher than this [11,47]. 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.

**Table 3.3. Threshold levels of Crude Mortality Rate and Infant Mortality Rate in camps**

| | *Mortality rates* |
|---|---|
| **Crude Mortality Rate** | 1 death/10,000/day |
| **Infant Mortality Rate** | ± 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.

**Table 3.4. Indicative acceptable incidence rates and specific mortality rates in camps for displaced persons or refugees [72]**

| | ***Incidence rate*** *(in cases/10,000/week)* | ***Mortality rate*** *(in deaths/10,000/week)* |
|---|---|---|
| **Diarrhoea total** | 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 [72].