Economic impact of foodborne illness

What is damaging and distressing at the level of the individual also has serious implications on a far larger scale. In developed countries efforts to quantify the economic impact of foodborne illness are comparatively recent, but it is clear from these that foodborne illness is a major burden on the economy. Costs arise from a number of different sources and are incurred both by the individual and by society at large. These costs include loss of income by the affected individual, cost of health care, loss of productivity due to absenteeism, costs of investigation of an outbreak, loss of income due to closure of businesses and loss of sales when consumers avoid particular products. In 1989 it was estimated that the total cost of bacterial foodborne illness to the United States economy was US$ 6,777,000,000. In developing countries, where the problem of diarrhoeal disease is far greater, the effect on economic activity and development can only be far more severe.

KEY POINTS

- Food is essential for health and well-being.
- Food may also be a cause of illness.
- Foods may be intrinsically toxic or may be contaminated with toxic chemicals or pathogenic organisms.
- Foodborne illness is extensively under-reported.
- Microorganisms (bacteria, viruses, moulds and parasites) are the most important cause of foodborne illness.
- Bacteria are generally most important.
- Most foodborne illness is associated with gastrointestinal symptoms of nausea, vomiting, stomach pains and diarrhoea.
- Foodborne illness is caused by two mechanisms: infection and intoxication.
- The infectious dose varies between organisms and between individuals.
- Foodborne illness can have seriously damaging effects on individuals, particularly young children, and on society as a whole.

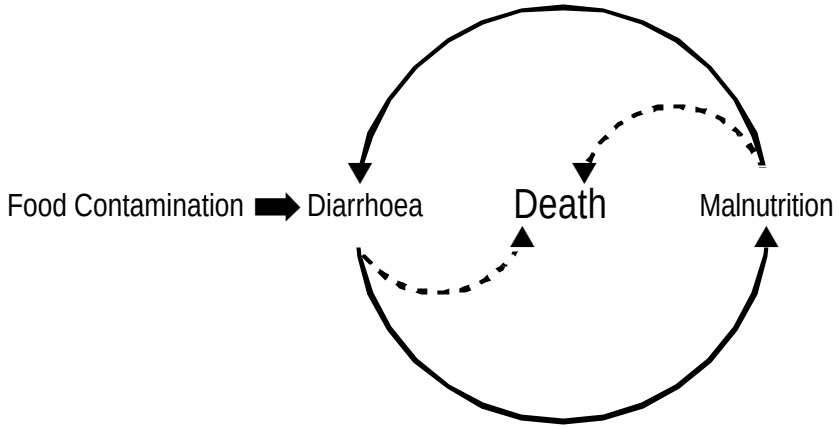
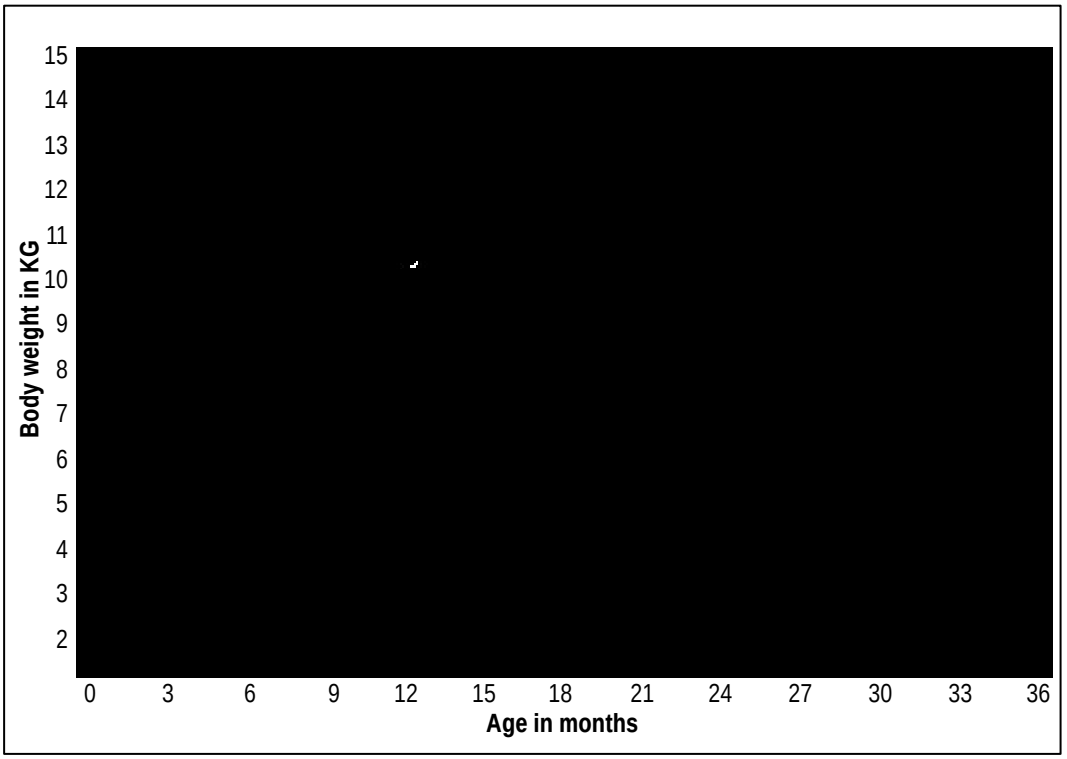


Figure 1.3 ***The malnutrition and diarrhoea cycle***



Source : Mata, LJ Nutrition and infection. Protein Advisory Group bulletin (1971)

Figure 1.4 ***Growth pattern of a child with frequent episodes of diarrhoea and other infections*** (The horizontal bars indicate the duration of the infectious disease)

Table 1.7 ***Examples of secondary disease state resulting from foodborne infections***

Disease	Associated complication
Brucellosis	Aortitis, orchitis, meningitis, pericarditis, spondylitis
Campylobacteriosis	Arthritis, carditis, cholecystitis, colitis, endocarditis, erythema nodosum, Guillain-Barré syndrome, haemolytic-uraemic syndrome, meningitis, pancreatitis,septicaemia
E.coli (EPEC & EHEC types) infections	Erythema nodosum, haemolytic-uraemic syndrome, seronegative arthropathy
Listeriosis	Meningitis, endocarditis, osteomyelitis, abortion and stillbirth, death
Salmonellosis	Aortitis, cholecystitis, colitis, endocarditis, orchitis, meningitis, myocarditis, osteomyelitis, pancreatitis, Reiter's syndrome, rheumatoid syndromes, septicaemia, splenic abscess, thyroiditis
Shigellosis	Erythema nodosum, haemolytic-uraemic syndrome, peripheral neuropathy, pneumonia, Reiter's syndrome, septicaemia, splenic abscess, synovitis
Taeniasis	Arthritis
Toxoplasmosis	Foetus malformation, congenital blindness
Yersiniosis	Arthritis, cholangitis, erythema nodosum, liver and splenic abcesses, lymphadenitis, pneumonia, pyomositis, Reiter's syndrome, septicaemia, spondylitis, Still's disease

Source: Mossel, 1988.

foodborne microorganisms (Table 1.7). In an outbreak of salmonellosis in Chicago in 1985, caused by contaminated pasteurized milk, more than 2% of the 170,000-200,000 people infected suffered from reactive arthritis as a result of their infection (*3*). Guillain-Barré syndrome is a serious and potentially life-threatening neurological disease characterized by acute weakness, autonomic dysfunction and respiratory insufficiency. It is a chronic sequela associated with acute gastrointestinal infection particularly by *Campylobacter jejuni*.

In developing countries, diarrhoeal diseases, particularly infant diarrhoea, are a major public health problem. It has been estimated that annually some 1500 million children under five years of age suffer from diarrhoea and over 3 million die as a result (*4*). Individual children experience on average 3.3 episodes of diarrhoea each year, though in some areas the number of episodes may exceed 9 and children can be suffering from diarrhoea for more than 15% of their young lives. The immediate cause of death from diarrhoeal disease is usually the dehydration that results from the loss of fluid and electrolytes in diarrhoeal stools, but diarrhoea can also have other serious health consequences. It may lead to malnutrition since food intake is reduced either as a result of loss of appetite or the withholding of food, and those nutrients that are ingested are poorly absorbed or simply lost by being swept out with the diarrhoeal stools. Malnutrition in its turn can predispose children to longer episodes of diarrhoea as well as other infections, aggravating the problem still further. This can result in a downward spiral of increasingly poor health which, unless it is broken in some way, will lead ultimately to premature death (Figure 1.3). Even where this does not proceed inexorably to a fatal end, the physical and mental growth of the child is severely impaired. This is shown in Figure 1.4 which records the effect of repeated bouts of diarrhoea and other illnesses on a child's development.

differ appreciably. *Shigella* and enterotoxigenic *E. coli* (ETEC) are otherwise very similar organisms but estimates of their respective infective doses are markedly different, reflecting differences in their virulence.

Susceptibility to infection can vary with a range of factors such as age, general health, nutrition, immune status and whether a person is undergoing medical treatment. Listeriosis can be mild or even asymptomatic in some individuals but can be severe and often life-threatening in the unborn child. In people with low gastric acidity, increased survival of ingested pathogens can reduce the required infective dose, thereby increasing the risk of infection. This is often found in the elderly and may help explain their increased susceptibility to foodborne infections. The food that is the vehicle of infection may also help reduce the infectious dose by protecting the pathogen from the lethal effect of the stomach's acidity. This has been noted particularly with fatty foods such as salami, cheese, chocolate and ice cream where low numbers of salmonella have been implicated in foodborne disease outbreaks (Table 1.6).

Where the infectious dose is high, the food vehicle can play a very specific role in the illness. Depending on the food's composition and conditions of storage, a pathogen present at low and possibly harmless levels may grow to numbers sufficient to produce illness. The speed with which bacteria can grow is described in more detail in Chapter 2.

Health consequences of foodborne illness

For most adults in the industrialized world, incidents of foodborne illness are unpleasant but are generally mild and self-limiting indispositions that are restricted to gastroenteritis and are not usually life-threatening. Exceptions occur with particularly susceptible individuals such as the very old or very young, pregnant women or those who are already very sick or weak for some other reason. These vulnerable groups constitute quite a large proportion of the population and for many of them diarrhoeal disease can be fatal.

A number of foodborne pathogens such as *Clostridium botulinum* are also associated with acute extraintestinal (systemic) disease. *C. botulinum* causes a severe neuroparalytic syndrome which is often fatal. The mortality rate in outbreaks in the United States between 1976 and 1984 was 7.5% but it can be substantially higher (*3*). Survival in cases of botulism is critically dependent on early diagnosis and treatment.

Sometimes extra-intestinal disease transmitted by food is particularly associated with certain susceptible individuals. For example, infection by *Listeria monocytogenes* can vary from a mild, flu-like illness to meningitis and meningoencephalitis. It is particularly serious in pregnant women; the mother may experience relatively mild symptoms but infection of the fetus can result in abortion, stillbirth or premature labour. Listeriosis is also more than 300 times more common in AIDS patients than in the general population. Cancer patients and other immunocompromised individuals are subject to bacteraemia caused by foodborne bacteria. Verotoxin-producing *E. coli* generally results in a bloody diarrhoea but can cause the haemolytic uraemic syndrome, characterized by thrombocytopaenia, haemolytic anaemia and acute kidney failure, particularly in children.

Some chronic diseases, particularly arthritic conditions, can be triggered by

Since the toxin is ingested with the food there is no direct person-to-person spread, as can occur with some enteric infections, and the incubation period (the time between consumption of the food and the appearance of symptoms) tends to be shorter, generally of the order of one or two hours or even less in some cases. This is because the toxin begins to act as soon as it reaches the site of action, whereas with infections the microorganisms need time to multiply in the body.

There are some similarities here with other biotoxins such as mycotoxins and algal toxins, though algae differ from toxigenic bacteria and moulds in that they do not multiply in the food. Also, the health effects of mycotoxins tend to be long-term rather than acute (see Chapter 2).

Infectious dose

Infective pathogens can be introduced into the body from a variety of sources. In the past, it was thought that contaminated water was the main source of the pathogens that cause diarrhoea. This is probably still true in many cases, but it has been shown more recently that food may also be the vehicle of contamination in up to 70% of cases.

To cause illness, a sufficient number of cells must be consumed. This is known as the infectious dose. The infectious dose varies from one organism to another and from person to person. For *Campylobacter jejuni* the infectious dose is thought to be quite low, while relatively high numbers of non-typhoid *Salmonella* are normally required to produce illness. Experiments have been conducted where volunteers have consumed different levels of pathogens in order to determine the infectious dose. These results and data from the investigation of actual outbreaks give some indication of the numbers of bacteria required to produce illness, but they should be regarded only as a rough guide (Table 1.6).

Successful infection is the result of the interaction of two variable factors: the virulence of the pathogen (its ability to cause illness) and the susceptibility of the individual. The virulence of different *Salmonella* serotypes, for example, can

Table 1.6 ***Estimated infectious doses***

Escherichia coli			
enteropathogenic	10^6–10^{10}		
enterotoxigenic	10^6–10^8		
enteroinvasive	10^8		
enterohaemorrhagic	10^1–10^3		
Shigella	10^1–10^2		
Salmonella Typhi	$<10^3$		
Other salmonellae	10^5-10^7		
but:			
Salmonella Newport		60 – 230	in hamburger
Salmonella Eastbourne		10 – 25	in chocolate
Salmonella Heidelberg		100 – 500	in cheese
Clostridium perfringens	10^6–10^8		
Campylobacter	500		
Vibrio cholerae	10^6		
Vibrio parahaemolyticus	10^5–10^7		

the normal functions of the gut are upset in some way.

The gastrointestinal tract or gut is not an internal organ of the body but a tube running through it where foods are digested and absorbed, and unwanted waste products are expelled. In addition to absorption of nutrients from foods, absorption and secretion of water are important gut functions. Water absorption normally exceeds secretion. Each day, a typical adult will ingest about two litres of water. To this must be added saliva and secretions from the stomach, pancreas and liver which altogether make a total of 8-10 litres entering the small intestine daily. About 90% of this fluid is absorbed before it enters the large intestine where 80-90% of the remainder is absorbed. Changes in the small intestine that either decrease absorption or increase secretion will reduce overall absorption and result in a larger fluid flow into the large intestine. If this exceeds the relatively limited absorptive capacity of the large intestine then diarrhoea occurs.

Bacteria cause foodborne illness by two mechanisms: infection and intoxication. The latter can also be caused by chemical contaminants and naturally occurring toxins.

Infection

Infection occurs when living bacteria are ingested with food in numbers sufficient for some to survive the acidity of the stomach, one of the body's principal protective barriers. These survivors then pass into the small intestine where they multiply and produce symptoms.

Infections can be invasive or non-invasive. In non-invasive infections, the organism attaches itself to the gut surface or epithelium to prevent itself from being washed out by the rapid flow of material through the gut. It then multiplies, colonizing the surface. In some cases, such as infection with enteropathogenic *Escherichia coli*, this produces changes in the gut epithelium which reduce its absorptive capacity or cause fluid secretion. Colonizing bacteria can also produce enterotoxins; toxins that alter the function of the cells lining the gut and cause them to secrete water and electrolytes into the intestine to produce a profuse watery diarrhoea. A notable example of this is cholera, but a similar sequence of events occurs with enterotoxigenic *E. coli* infections.

Invasive pathogens are not confined to the intestinal lumen but can penetrate the cells lining the gut. In some cases their penetration is limited to the immediate vicinity of the gut, as with the non-typhoid salmonellas. Some pathogens invade the mucosa of the large intestine rather than the small intestine, producing inflammation, superficial abscesses and ulcers, and the passage of dysenteric stools containing blood, pus and large amounts of mucus. In other cases, microbial invasion is not restricted to the gut's immediate locality and the organism spreads further through the body, producing symptoms other than diarrhoea at sites remote from the gut itself, as for example in brucellosis, listeriosis, typhoid and paratyphoid fevers.

Illnesses caused by foodborne viruses and parasites are also broadly similar in that viable organisms gain access to their site of action in the body via the gastrointestinal tract.

Intoxication

With foodborne intoxications, the bacteria grow in the food producing a toxin. When the food is eaten, it is the toxin, rather than the microorganisms, that causes symptoms.

figures are collected, but it is thought to reflect an underlying increase in the number of cases as well.

A number of factors have contributed to this trend. Their relative importance varies between countries and between pathogens but some of the most significant are as follows:

- Increasing industrialization and urban living has meant that the food chain has become longer and more complex, increasing opportunities for contamination. It also means that more people are likely to be affected by a single breakdown in food hygiene.
- In poorer countries increased urbanization and rapid population growth have not been matched by development of the health-related infrastructure, including basic sanitation, and this has led to increased risk of contamination of the food and water supply.
- Increasing affluence in other areas has led to greater consumption of foods of animal origin such as meat, milk, poultry and eggs. These foods are recognized as more common vehicles of foodborne pathogens and this situation can be exacerbated by the methods of intensive production required to supply a larger market.
- There is greater international movement of both foods and people. Exotic *Salmonella* serotypes have been introduced into Europe and the United States as a result of the importation of animal feeds. A number of outbreaks of illness associated with imported foods have also been recorded. Tourism is one of the world's major growth industries and every year more and more people travel abroad where they are exposed to increased risk of contracting foodborne illness.
- Changing lifestyles also means that food preparation may be in the hands of the relatively inexperienced as more mothers go out to work and more people eat pre-prepared foods, meals from catering establishments or food from street vendors.
- An increasing proportion of the population is more susceptible to foodborne illness. This includes the malnourished, the elderly, those who have some underlying condition such as liver disease and those who are immunocompromised as a result of infections such as HIV and immunosuppressive medical treatment.

Foodborne illness: its definition and nature

The term "food poisoning" has often been used in some countries, but it is an expression that can sometimes be restrictive or misleading. *Foodborne illness* or *foodborne disease* are now the generally preferred terms. Foodborne disease can be defined as:

> "any disease of an infectious or toxic nature caused by or thought to be caused by the consumption of food or water".

Though there are a number of important exceptions that will be described later, in most cases and in most people's minds, the illnesses caused by foodborne microorganisms, principally bacteria, are associated with gastrointestinal symptoms of nausea, vomiting, stomach pains and diarrhoea. Since diarrhoea is a common clinical symptom in foodborne diseases, many of these diseases are referred to as "diarrhoeal diseases". These occur when

foodborne in origin or may not be reported to the relevant authority for recording. Estimates vary but it is generally believed that in developed countries less than 10%, or even only 1%, of cases of foodborne illnesses ever reach official statistics. In countries with fewer resources, under-reporting must be even greater, with probably less than 1% of cases being reported. Studies in some countries point to an under-reporting factor of up to 350 in some cases.

Statistics from both developed and developing countries show an increasing trend in foodborne illness over recent years (Figure 1.2). In part, this is probably due to improvements in the way the

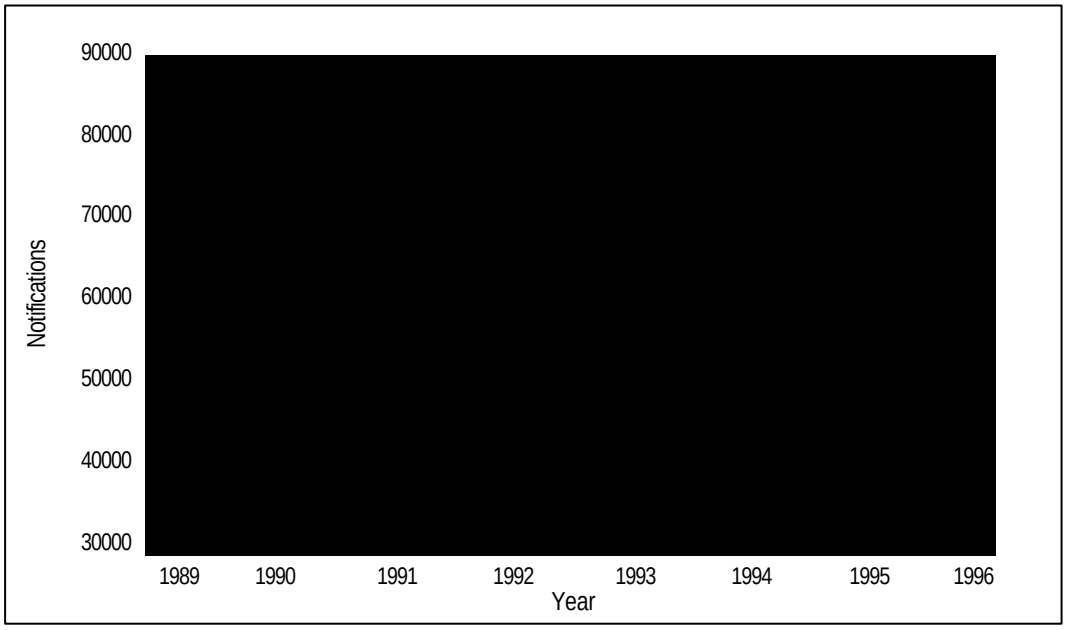


Figure 1.2a ***Foodborne illness : annual notifications, England and Wales***

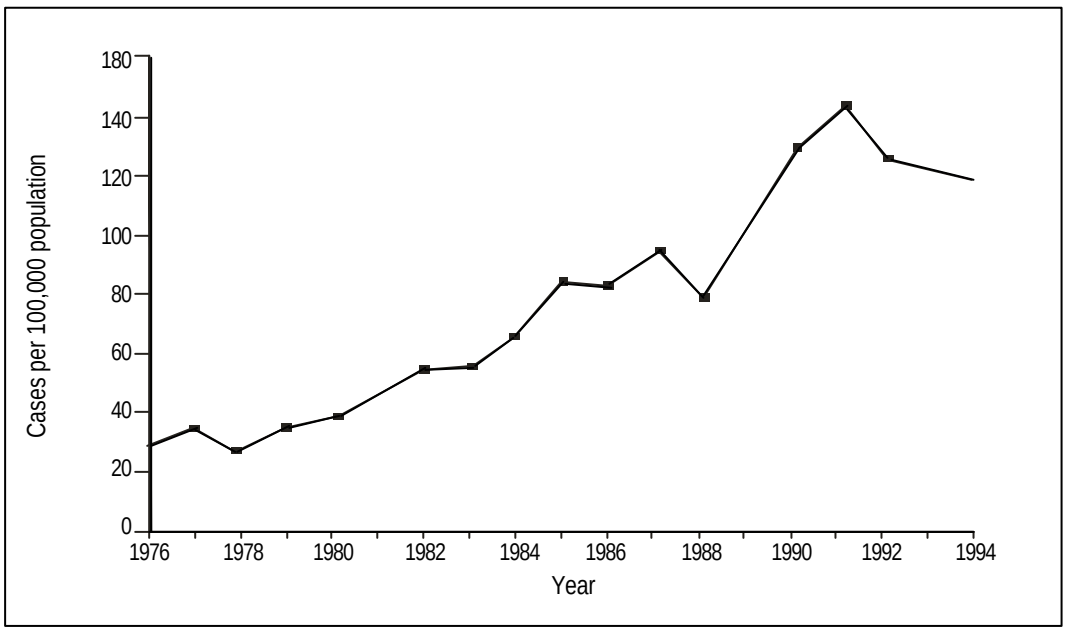
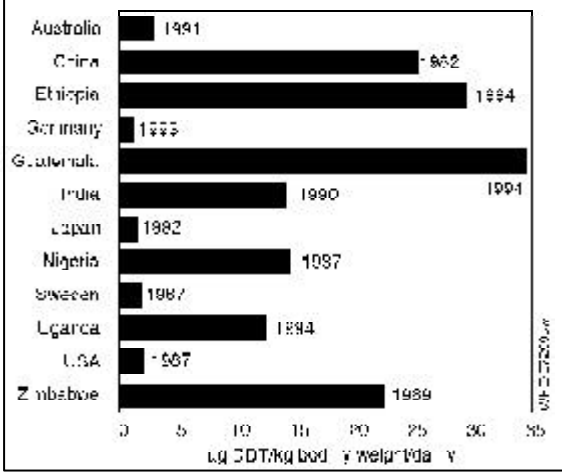


Figure 1.2b ***Incidence of foodborne disease in Venezuela***



DDT complex (DDT and its degradation products) contaminates food mainly as a result of its earlier use in agriculture and public health. While DDT is now banned in most countries for agricultural uses, the persistence and fat solubility of DDT have resulted in widespread contamination of the food chain. Levels of DDT in breast milk reflect the exposure of the mother to DDT and is a good indicator of the levels of DDT in the food supply. Breast milk is also the sole food for the first few months of life and dietary intake of DDT complex by infants in some countries approaches or exceeds the WHO recommended provisional tolerable intake of 20 µg DDT/kg body weight/day.

Source: GEMS/Food WHO document (WHO/FSF/FOS/97.9)

Figure 1.1 ***Dietary intake of DDT by infants from human milk***

Data collected by the Food Contamination Monitoring and Assessment Programme (GEMS/Food) indicate that in many countries the trend in chemical contaminant levels is generally downwards. This is most apparent in developed countries where exposure to these contaminants is often much lower than in developing countries (Figure 1.1).

Factors contributing to this disparity are discussed in Chapter 2. The general overall improvement is due to increased restriction of the use of toxic chemicals and pesticides that persist in the environment, and improved control of environmental pollution. Available data on foodborne illness of biological origin provide a strong contrast to this reduction in chemical contamination.

Several different types of organism can cause foodborne illness. Bacteria, single-celled organisms with typical dimensions of around 1µm (10^{-6}m), are the most important and well studied foodborne pathogens. A key factor is their ability to multiply in food, thus increasing the hazard they pose. This is discussed in Chapter 2. Filamentous fungi (moulds) can also grow in foods and some produce toxic substances called mycotoxins.

A number of human viruses can be transmitted by food and human diseases caused by protozoa, helminths and nematodes that are animal parasites are problems of emerging importance in a number of countries. These differ from most bacterial foodborne illnesses in that the causative organism does not multiply in the food itself. A brief description of the major foodborne pathogens and some of their key features is presented as Appendix 1. Most of the following is concerned primarily with bacterial pathogens, though specific aspects of other pathogens are mentioned where appropriate.

Extent of foodborne illness

Many developed countries have sophisticated systems for collecting data on the incidence and causes of foodborne illness. Yet it is known that these data represent only a fraction of the number of cases that occur. Infected individuals may not seek medical advice, and if they do their illness may not be recognized as

Table 1.4 ***Mean daily intakes (mg) of natural food toxicants***

Class of compound (food source)	Population	
	Total	Vegetarian
Glucosinolates (brassicas)	50	110
Glycoalkaloids (potatoes)	13	70 - 90
Saponins (legumes)	15	100 (*220)
Isoflavones (soya)	<1	105

* U.K. vegetarian population of East African origin

Source: Morgan, MRA. and Fenwick, GR National foodborne toxicants. Lancet, 15 December 1990, p. 1492/1495.

In most cases foods are not contaminated intentionally but rather from carelessness or insufficient education or training in food safety. In some cases, contamination may be deliberate as, for example, in the misuse of food additives such as prohibited colouring. In one serious case in Spain, contaminated industrial rapeseed oil was sold for human consumption, killing more than 500 people and crippling more than 20,000 (*1*).

How the relative importance of these hazards is perceived depends on who you ask. Surveys indicate that, as far as the general public is concerned, hazards associated with pesticide residues, environmental chemical contaminants and the use of food additives cause most concern. Yet experience shows that most outbreaks of foodborne disease are associated with microbiological contamination.

This is reflected in the available statistics on the etiology of foodborne illness. (Table 1.5). One study estimated that people are 100,000 times more likely to become ill as a result of microorganisms in food than as a result of pesticide residues (*2*).

Table 1.5 ***Etiology of foodborne disease outbreaks (with known etiology) in Latin America and the Caribbean, 1995-1997***

Etiological agent	Percentage of outbreaks	Percentage of cases involved in outbreaks
Bacteria	**46.3**	**83.03**
Of which:		
Bacillus cereus	1.3	1.2
Clostridium perfringens	4.2	4.1
Clostridium botulinum	0.4	0.1
Escherichia coli	11.4	7.8
Salmonella	37.0	43.1
Shigella spp.	3.1	21.9
Staphylocccus aureus	36.6	19.5
Vibrio cholerae	4.2	0.9
Vibrio parahemolyticus	0.2	0.4
Other	1.6	1.0
Total	100.0	100.0
Viruses	**1.8**	**3.7**
Parasites	**1.8**	**2.9**
Marine toxins	**44.2**	**8.0**
Plant toxins	**0.4**	**0.1**
Chemical substances	**5.4**	**2.3**
Total	**100.0**	**100.0**

Source: Adapted from data provided by the Pan American Institute for Food Protection and Zoonoses, INPPAZ, PAHO/ WHO 1998

Table 1.2 ***Examples of vitamin and mineral deficiency syndromes***

Micronutrient	Deficiency syndrome
A	Night blindness, xeropthalmia
Thiamine	Beriberi, Wernicke's encephalopathy; Korsakoff's psychosis
Niacin	Pellagra
Riboflavin	Mucosal lesions
Pyridoxine	Glossitis, neuropathy
Folate	Megaloblastosis, villus atrophy
B_{12}	Pernicious anaemia, megaloblastosis, neuropathy
C	Scurvy
D	Rickets, osteomalocia
K	Hypoprothrombinaemia
Iodine	Goitre, cretinism
Iron	Anaemia

and established processing and handling procedures are followed, the majority do not cause serious problems. Natural food toxins are described in more detail in Chapter 2 but a few examples are given in Table 1.3 and estimates for some mean daily intakes in the United Kingdom are presented in Table 1.4.

Other foodborne hazards can be described as extrinsic, indicating that their presence is a result of contamination of the food. This includes contamination with industrial chemicals or pesticide residues, right through to the presence of pathogenic bacteria or parasites. The range of possibilities is summarized in Table 1.3.

Table 1.3 ***Causes of foodborne illness***

	Examples
INTRINSIC HAZARDS	
(Natural Toxins or Antinutritional Factors)	oxalic acid (rhubarb, spinach)
	alkaloids
	solanine (potatoes)
	dioscorine (yams)
	cyanide (cassava, lima beans)
	haemagglutinin (red kidney beans)
	protease inhibitors (legumes)
	phytic acid (bran)
	amatoxin, psilocybin and others (toxic mushroom)
EXTRINSIC HAZARDS	
Chemical Contamination	dioxins, PCBs
	heavy metals
	cadmium
	mercury
	lead
	pesticide residues
Biological Contamination	Bacteria
	causing infection e.g. *Salmonella*
	causing intoxication e.g. *C. botulinum*
	Parasites
	helminths e.g. roundworms
	protozoa e.g. *Giardia lamblia*
	Viruses e.g. Hepatitis A, Small Round-Structured Viruses (SRSVs)
	Fungi/mycotoxins e.g. aflatoxin
	Algae (e.g.dinoflagellates leading to paralytic shellfish poisoning)

Chapter 1
Foodborne illness

Food in health and disease

Food is essential both for growth and for the maintenance of life. It supplies the energy and materials required to build and replace tissues, to carry out work and to maintain the body's defences against disease.

Food can also be responsible for ill-health. Failure to consume enough of the right kind of food will impede growth and impair health. For example, protein-energy malnutrition can lead to a range of clinical manifestations. These vary from marasmus, where consumption of protein, dietary energy and other nutrients are chronically reduced, to kwashiorkor (sometimes thought to be associated with an over-reliance on low protein staples) which results in a quantitative and qualitative deficiency of protein (Table 1.1).

Even when a diet provides enough protein and energy, it may not supply sufficient essential minerals or vitamins and may thus give rise to characteristic deficiency disorders (Table 1.2).

Illness can also result from what a food contains rather than from what it lacks. Some hazards of this kind are described as being intrinsic to the food in the sense that they are normal and natural constituents of the food. Many common food plants, for instance, contain toxic compounds designed to deter predators or invading microorganisms. Their intake is inevitably higher in those people with a largely vegetarian diet.

However, in most cases where the food supply is generally varied and plentiful,

Table 1.1 ***Classification of severe protein-energy malnutrition in children***

Weight for age*	With oedema	Without oedema
60 –80%	Kwashiorkor	Undernutrition
Less than 60%	Marasmic kashiorkor	Marasmus

* As % of standard (National Centre for Health Statistics) weight

Source: Tomkins, AM Nutrition in clinical medicine. In: Textbook of Medicine. RL Souhami and J Maxham (eds) 2nd edn. Churchill Livingstone, Edinburgh, 1994: p.106.