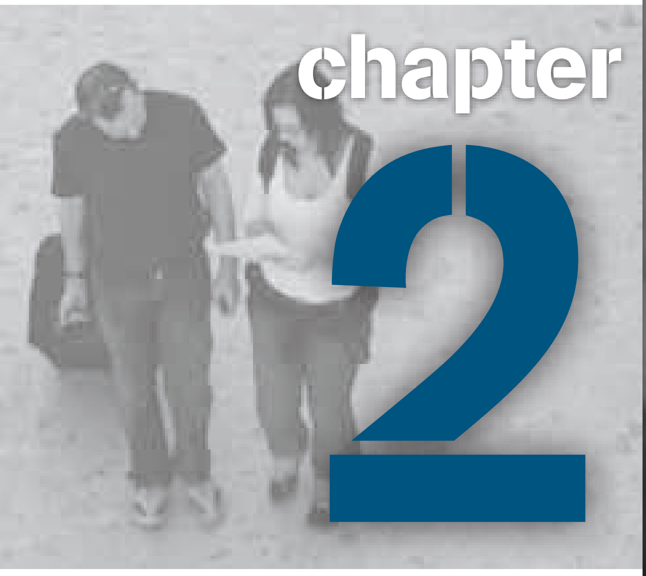
THREATS TO PUBLIC HEALTH SECURITY



chapter 2

Chapter 2 explores a range of threats to global public health security, as defined by the International Health Regulations (2005), which result from human actions or causes, from human interaction with the environment, and from sudden chemical and radioactive events, including industrial accidents and natural phenomena. It begins by illustrating how inadequate investment in public health, resulting from a false sense of security in the absence of infectious disease outbreaks, has led to reduced vigilance and a relaxing of adherence to effective prevention programmes.

The new regulations are no longer limited to the scope of their original six diseases – cholera, plague, relapsing fever, smallpox, typhus and yellow fever. Rather, they address "illness or medical conditions, irrespective of origin or source that present or could present significant harm to humans" (*1*).

Such threats to public health security, be they epidemics of infectious diseases, natural disasters, chemical emergencies or certain other acute health events, can be traced to one or more causes. The causes may be natural, environmental, industrial, accidental or deliberate but – more often than not – they are related to human behaviour.

This chapter explores the threats to global public health security, as defined by IHR (2005), which can result from human action or inaction and natural events. The importance of the more fundamental causes of health security embedded in the social and political environments that foster inequities within and between groups of people will be discussed in subsequent publications.

HUMAN CAUSES OF PUBLIC HEALTH INSECURITY

Human behaviour that determines public health security includes decisions and actions taken by individuals at all levels – for example, political leaders, policy-makers, military commanders, public health specialists and the general population – which have dramatic health consequences, both negative and positive. The following examples illustrate the public health security repercussions when human behaviour is influenced by situations of conflict and displacement or attitudes of complacency, lack of commitment, and mistrust and misinformation.

Inadequate investment

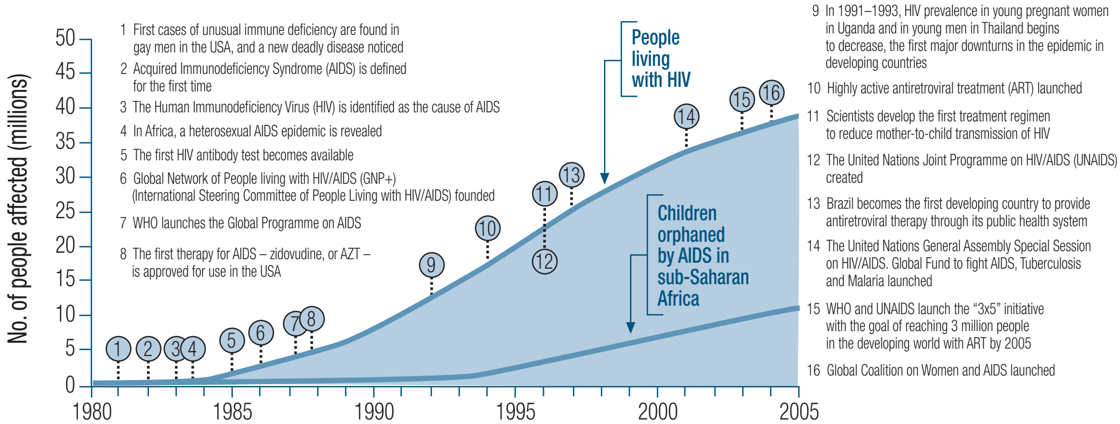
Inadequate investment in public health, resulting from a false sense of security in the absence of infectious disease outbreaks, can lead to reduced vigilance and a relaxing of adherence to effective prevention programmes. For example, following the widespread use of insecticides in large-scale, systematic control programmes, by the late 1960s most of the important vector-borne diseases were no longer considered major public health problems outside of sub-Saharan Africa. Control programmes then lapsed as resources dwindled, and the training and employment of specialists declined. The result was that within the next 20 years, many important vector-borne diseases including African trypanosomiasis, dengue and dengue haemorrhagic fever, and malaria emerged in new areas or re-emerged in areas previously affected. Urbanization and increasing international trade and travel have contributed to rapid spread of dengue viruses and their vectors. Dengue caused an unprecedented pandemic in 1998, with 1.2 million cases reported to WHO from 56 countries. Since then, dengue epidemics have continued, affecting millions of people from Latin America to South-East Asia. Globally, the average annual number of cases reported to WHO has nearly doubled in each of the last four decades.

Inadequate surveillance results from a lack of commitment to build effective health systems capable of monitoring a country's health status. This is illustrated by the rapid global emergence and spread of HIV/AIDS in the 1970s. The presence of a new health threat was not detected by what were invariably weak health systems in many developing countries, and only belatedly became a matter of international concern when it manifested itself in the first cases in the United States. Figure 2.1 shows developments over 25 years dating from this event at the beginning of the 1980s.

Surveillance is the cornerstone of public health security. Without appropriately designed and functioning surveillance systems, unusual but identifiable health events cannot be detected, monitored for their likely impact, quantified over time or measured for the effectiveness of interventions put in place to counteract them (see Figure 2.2).

The inability of surveillance systems to recognize new disease trends is not confined to poorer countries. For instance, the first cases of AIDS were detected and characterized in the United States not by surveillance but by serendipity. Epidemiologists at the United States Centers for Disease Control and Prevention (CDC) observed an unusual number of requests to their orphan drug repository for antimicrobials to treat pneumonia

Figure 2.1 Twenty-five years of HIV/AIDS



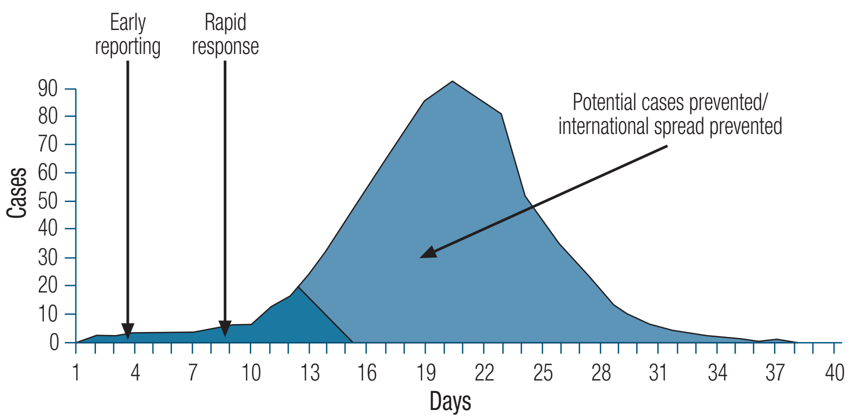
Source: *2006 Report on the global AIDS epidemic.* Geneva, Joint United Nations Programme on HIV/AIDS, 2006.

Viruses, such as dengue, flourish in slums that result from uncontrolled urbanization.

caused by *Pneumocystis carinii*, a rare parasitic infection but one that is common in AIDS cases (*2*). Yet, what soon became known as AIDS had been occurring for perhaps many years in Africa and Haiti – poorly detected and poorly characterized. Inadequate surveillance systems, universal in low and middle income countries, are not capable of recognizing unusual health events. Similarly, because these systems are poorly funded and diagnostic facilities are limited, the systems do not allow for the identification and monitoring of any but a few specific illnesses, for example, tuberculous. Ministries of health are doubly compromised because, without better surveillance, it is difficult for them to mount interventions or measure their effectiveness.

In addition to limited disease surveillance capacity and data, early efforts to control the AIDS epidemic were also hampered by a lack of solid data on sexual behaviour, whether in Africa, Haiti, or the United States and other industrialized countries. In the

Figure 2.2 Global outbreaks, the challenge: late reporting and response



industrialized world, the 1960s was a period of scientific advances and rapid social change. The widespread availability of oral contraception contributed to the apparent liberalization of sexual mores that was furthered by the profound social changes of that period. Coupled with these developments, attitudes towards and among homosexually active men became more liberal, particularly in the big cities of the United States, with a marked migration of gay men to certain key cities. Despite these significant social and attitudinal changes, no scientific study of sexual behaviour, and its relationship to the emergence of sexually transmitted diseases, had been carried out in the United States since the 1950s, and these were long out of date by the time AIDS appeared as a major public health threat.

As inadequate as behavioural data were in the industrialized world, they were practically non-existent in the developing world. The understanding of HIV/AIDS in the context of sexuality in the developing world took years to develop and is still poorly understood. Only in recent years, a quarter of a century after the description of AIDS, have population-based surveys of sexual behaviour (demographic and health surveys) been conducted that allow a better understanding – supported by valid scientific evidence – of sexual behaviour in countries on multiple continents heavily affected by HIV/AIDS (*3*).

Against a background of armed conflict, families have less access to health care and are more vulnerable to disease.

Unexpected policy changes

Even with reliable operations in place, unexpected policy changes in public health systems can have lethal and costly repercussions. Such was the case in August 2003, when unsubstantiated claims originating in northern Nigeria that the oral polio vaccine (OPV) was unsafe and could sterilize young children led to governments ordering the suspension of polio immunization in two northern states and substantial reductions in polio immunization coverage in a number of others. The result was a large outbreak of poliomyelitis across northern Nigeria and the reinfection of previously polio-free areas in the south of the country. This outbreak eventually paralysed thousands of children in Nigeria. The disease also spread from northern Nigeria to polio-free countries.

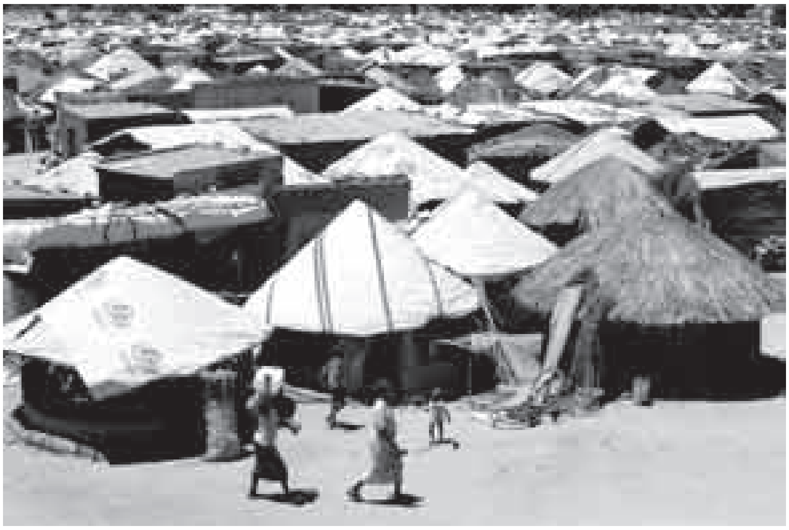
At the beginning of 2003, only seven countries in the world remained infected: Afghanistan, Egypt, India, Niger, Nigeria, Pakistan and Somalia. By the end of 2006, 19 polio-free countries in Africa, Asia and the Middle East had experienced outbreaks traceable genetically to the Nigerian virus. Mass outbreak response activities across these countries cost more than US$ 450 million. In July 2004, polio immunization resumed throughout northern Nigeria, as a result of a tremendous collaborative effort between state and federal authorities and traditional and religious leaders, supported by the high-level engagement of organizations such as the African Union and the Organization of the Islamic Conference – thus showing that collaboration and partnership that extend beyond the traditional discipline of health can bring tremendous change for the good of global public health security.

Public health consequences of conflict

When governments or armed groups engage in armed conflict, a collateral impact is often the destruction or weakening of health systems, resulting in their diminished capacity to detect, prevent and respond to infectious disease outbreaks, which in turn reduces the concerned population's access to health care. Such was the case in Angola. One consequence of the 27-year civil war (1975–2002) was the spread of an outbreak of Marburg haemorrhagic fever in 2004–2005, which affected more than 200 people, 90% of whom died (see Box 2.1). Transmission of Marburg haemorrhagic fever, an infectious disease related to Ebola, is amplified in situations where poor health facilities are overcrowded and understaffed, and where lack of investment in hospitals and clinics results in sub-standard infection control.

Human population movements on a large scale as a result of war, conflict or natural catastrophes have been tragically common in recent years. The forced migration or displacement of large numbers of people often oblige them to live in crowded, unhygienic and impoverished conditions, which, in turn, heighten the risk of infectious disease epidemics. This was the cause of the cholera epidemic in the Democratic Republic of the Congo, in the aftermath of the crisis in Rwanda in 1994. In July of that year, between 500 000 and 800 000 people crossed the border to seek refuge in the outskirts of the Congolese city of Goma. During the first month after their arrival, close to 50 000 refugees died. The extremely high crude mortality rate of 20–35 per 10 000 per day can be associated with an explosive outbreak of combined cholera and shigella dysentery.

Overcrowding exposes displaced populations to infectious disease outbreaks.



Box 2.1 Marburg haemorrhagic fever and health systems in conflict situations

Angola had witnessed almost three decades of conflict, which, apart from the immediate human casualties, had left the country with a severely damaged health infrastructure, a hospital system in dire need of basic equipment and supplies, inadequate communication and transport systems, and a population weakened by economic hardship. These weaknesses hampered efforts to contain the outbreak of Marburg haemorrhagic fever in 2005, as containment of an infectious disease depends on active surveillance mechanisms, the prompt detection and isolation of new cases in specially designated and equipped facilities, and the rapid tracing of contacts (*4*). The Angolan authorities, with the support of the international community, launched a massive effort to reconstruct health and transport systems and to improve the population's nutrition. Despite their best attempts, 70% of the population is still without basic health care (*5*).

The outbreak of Marburg haemorrhagic fever in Angola was the largest on record, with the highest fatality rate, but it was not the only outbreak to occur following a conflict situation (*6*). Another large outbreak in the eastern region of the Democratic Republic of the Congo, made inaccessible by the conflict, occurred in late 1998. As many as 154 cases were reported, with 128 deaths. These were followed by sporadic cases with small chains of transmission over a two-year period. The war delayed access and evaluation, so that supplies were severely limited in all the health facilities in the region (*7*).

The speed of transmission and the high attack rate were related to the contamination with *Vibrio cholerae* of the only available source of water, Lake Kivu, and the absence of proper housing and sanitation (*8*).

The problems associated with people living in high density environments are not limited to emergency areas such as refugee camps. Rapid urbanization that has become common in many countries in the 21st century means that cities are now home to over half the world's population. Uncontrolled urbanization is characterized by expanding metropolitan areas, worsening environmental degradation, increasing inequity and the growth and proliferation of slums and informal settlements. Indeed, a third of global urban dwellers, or a billion people, live in slums and informal settlements where they exist in cramped, congested living conditions, without access to safe water, sanitation, safe food, decent shelter or meaningful employment.

Microbial evolution and antibiotic resistance

Another category of threats to public health security concerns the continuing and increasing evolution of resistance to anti-infective drugs, which is a major factor in the emergence and re-emergence of infectious diseases (*9*). Bacteria can develop resistance to antibiotics through spontaneous mutation and through the exchange of genes between strains and species of bacteria.

Bacteria often live in harmony with other inhabitants of the Earth. However, since penicillin became widely available in 1942, and other antibiotics soon followed, the killing and growth-inhibitory effects of antibiotics have applied selective pressure that has reduced the number of susceptible strains, leading to the propagation of more resistant varieties of bacteria (*10*). The selection and spread of these varieties are facilitated paradoxically by either over-prescribing or under-prescribing of drugs,

Contaminated lakes and rivers are often people's only sources of drinking-water.

poor compliance with recommended dosages, and unregulated sale by non-health workers (*9*). Antibiotics were initially developed for the treatment of infectious diseases in people, but eventually the same drugs also began to be used for the treatment of animals and plants. Often the same microbes circulate among their human, animal and agricultural hosts, providing opportunities for swapping or exchanging resistant genes and thus assisting the evolution and spread of resistance (*10*).

The discoverer of penicillin, Alexander Fleming, first warned of the potential importance of the development of resistance (*11*). Soon the evidence became alarming. In 1946, a hospital in the United Kingdom reported that 14% of all *Staphylococcus aureus* infections were resistant to penicillin. By 1950, this proportion had increased to 59%. In the 1990s, penicillin-resistant *S. aureus* had attained levels greater than 80% both in hospitals and in the community (see Figure 2.3).

It is not only bacteria that develop resistance to drugs: parasites do so too. By 1976, chloroquine-resistant *Plasmodium falciparum* malaria was highly prevalent in South-East Asia and 10 years later was found worldwide, as was high-level resistance to two back-up drugs, sulfadoxine pyrimethamine and mefloquine (*9*). The development of parasitic and bacterial resistance to drugs commonly used to treat malaria and tuberculosis is a grave threat to public health. The same is true for viruses, as shown by the emerging resistance to anti-HIV drugs (*9*).

Organisms that are resistant to multiple anti-infective drugs are not unusual (*12*). The results of resistance are very serious in terms of increased mortality, with a doubling of mortality being observed in some resistant infections as well as a need for an increase in the length of treatment with the more expensive anti-infective drugs or drug combinations. Complicating the matter, fewer new antibiotics are reaching the market with no new class of broad-spectrum antibiotic likely to appear soon. New public-private partnerships, however, are slowly beginning to fill the pipeline of new drugs for diseases such as tuberculosis and malaria, many of them with initial funding from the Bill and Melinda Gates Foundation (*9*).

The spread of resistance worldwide is one reason why efforts to detect and respond to outbreaks of infectious diseases as quickly as possible are so important, as is the wider need to rebuild and strengthen health systems, improve water and sanitation systems, minimize the impact of natural and human-influenced changes in the environment, effectively communicate information about the prevention of infectious diseases, and use anti-infective drugs appropriately (*9*). If the use of anti-infective drugs were better rationalized, the evolutionary pressure on bacteria would be altered and susceptible strains could again proliferate (*12*).

Figure 2.3 Evolution of penicillin resistance in *Staphylococcus aureus*: a continuing story

1928	Penicillin discovered
1942	Penicillin introduced
1945	Fleming warns of possible resistance
1946	14% hospital strains resistant
1950	59% hospital strains resistant
1960s–70s	Resistance spreads in communities
1980s–90s	Resistance exceeds 80% in communities, 95% in most hospitals

Animal husbandry and food processing

Human spongiform encephalopathy

In May 1995, the death of a 19-year-old man in the United Kingdom marked the first human death of what is now known to be variant Creutzfeldt-Jakob disease (vCJD) or human bovine spongiform encephalopathy (BSE). His illness and death demonstrate the health consequences of improper animal rendering and feeding practices that had begun during the 10-year period prior to his death. Briefly, the carcasses of cattle, including those that had been infected with the BSE-causing agent, were rendered into livestock feed. Some of the cattle consuming this feed then also became infected leading to an epidemic of BSE, commonly called "mad cow disease" because of the animals' uncharacteristically agitated behaviour. From October 1996 to November 2002, 129 cases of vCJD were reported in the United Kingdom, six in France and one each in Canada, Ireland, Italy and the United States.

The most likely source of human infection with vCJD is the consumption of meat contaminated with BSE. The crisis, therefore, led to the recognition of the need for government intervention along the entire "feed to food" continuum to ensure the safety of foodstuffs for human consumption. Trade was shown to adapt itself very quickly to the changing regulatory environment, with immense consequences for the United Kingdom market.

Only reinforced surveillance in humans and animals can expose how widely the agent was exported during the late 1980s and mid-1990s from its original European focus and how far this public health security threat extends. The recent identification in the United Kingdom of a fourth case of vCJD associated with a blood transfusion that was later found to be contaminated with vCJD caused additional concern (*13*). This is a reminder of the need for adequate investment in ensuring as safe a blood supply as possible, taking into account risks of disease transmission in each country.

Nipah virus

Nipah virus is an emerging viral pathogen that causes encephalitis – an inflammation of the brain – which is fatal in up to 75% of the people that it infects. The disease caused by Nipah virus was first recognized in Peninsular Malaysia in an outbreak which began in September 1998 and ended in April 1999. During that outbreak, 265 human cases including 105 deaths were reported (*14*). When the reports of a severe encephalitis outbreak began to accumulate, it was initially attributed to Japanese encephalitis, a disease which is prevalent in Malaysia.

The belief that this outbreak was due to Japanese encephalitis resulted in expensive and disruptive campaigns directed at mass immunization and mosquito control. These control efforts were ineffective because it was in fact a new disease caused by a previously unrecognized virus.

The majority of human cases were associated with direct contact with sick or dying pigs or fresh pig products. It was eventually recognized that commercially raised pigs, often housed near fruit orchards, were acting as the intermediate hosts of the new virus. Transmission among pigs and from pigs to humans is now thought to have occurred via the aerosol route in the former or following contact with throat or nasal secretions in the latter. The end of the outbreak coincided with the mass culling of more than 1 million pigs, which was part of the control strategy. In Singapore, there was a small related outbreak that infected 11 human cases resulting in one death. A further 89 individuals were subsequently shown by serological tests to have experienced an asymptomatic or mild infection of the disease. The Singapore outbreak ended following a ban on the importation of pigs from Malaysia.

Evidence from additional Nipah virus outbreaks since the events in Malaysia and Singapore suggests that the virus may have become more pathogenic for humans. In these cases, it seems that the virus can spread to humans without an intermediate amplifying host such as the pig, and that human-to-human transmission can occur with even casual contact. Some evidence points to amplification of transmission within the health-care setting. In the most recent of these outbreaks, consumption of contaminated food is considered the most likely route of exposure for several human infections. Moreover, evidence of Nipah virus infection in fruit bats has now been found in a broader range of countries than previously assumed.

The emergence and subsequent evolution of Nipah virus illustrate many of the public health problems caused by emerging pathogens. These include initial diagnostic confusion leading to delayed detection and inappropriate control measures, and high mortality in the absence of effective preventive or control measures, which becomes more difficult when control of an intermediate host, such as the pig, is no longer an option. Changes in the epidemiological behaviour of the virus underscore the need to be ready to adapt control measures as a new pathogen evolves.

WEATHER-RELATED EVENTS AND INFECTIOUS DISEASES

Intensifying climatic conditions, together with a range of environmental, epidemiological and socioeconomic factors, are bringing about changes in the exposure of populations to infectious diseases, as illustrated by the following example of Rift Valley fever.

Above-normal rainfall associated with the occurrence of the warm phase of the El Niño Southern Oscillation phenomenon is increasing the breeding sites of mosquitoes, with a consequent rise in the number of outbreaks of Rift Valley fever. From December 1997 to March 1998, the largest outbreak ever reported in East Africa occurred in

Above-normal rainfall increases the risk of vector-borne diseases.

Kenya, Somalia and the United Republic of Tanzania. The total number of human infections in the North Eastern Province of Kenya and southern Somalia alone was estimated at 89 000, with 478 "unexplained" deaths (*15*). Complications arising from Rift Valley fever in humans include retinopathy, blindness, meningo-encephalitis, haemorrhagic syndrome with jaundice, petechiae and death. The outbreaks in East Africa were linked to the higher than average rainfall – favouring the hatching of mosquito eggs – and a complex interaction between non-vaccinated cattle and the mosquitoes, which transmit the virus from animals to humans principally after feeding on infected animals. Female mosquitoes are also able to pass the infection to their offspring which spread the virus to animals on which they then feed, thus perpetuating a vicious circle of infection.

Animal immunization is only partially effective in preventing these outbreaks because it must be implemented prior to the beginning of an outbreak in animals and, if carried out during an outbreak, there is a risk of cross-infection from the reuse of needles and syringes.

After the 1997–1998 outbreaks, a new prevention strategy was developed based on two components: an accurate forecasting model, based on climatic conditions that can predict the emergence of Rift Valley fever 2–4 months in advance, and efficient veterinary public health services capable of implementing emergency mass animal immunization before the beginning of the animal outbreak.

Forecasting models and early warning systems for Rift Valley fever, based on satellite images and weather and climate forecasting data, were successfully developed to meet these requirements. In Africa and the Middle-East, collaboration with affected countries, space agencies (the United States National Aeronautics and Space Administration (NASA) and the International Reference Ionosphere (IRI) project), the Food and Agriculture Organization of the United Nations (FAO) and WHO made it possible to draw up a monthly map of the possible emergence zones for Rift Valley fever. These maps were used to inform the countries and help them with the early detection of cases. Ultimately, these forecasting alerts should allow authorities to implement measures to avert an impending epidemic by allowing implementation of mass animal immunization prior to the start of the animal outbreak and to conduct intensive social mobilization programmes aimed at changing risky behaviour.

On two occasions, the NASA/WHO monthly mapping of fever emergence was able to predict an animal outbreak one month before it surfaced. In November 2006, alert messages were sent to countries in the Horn of Africa. In addition, outbreaks of other arboviruses (dengue, West Nile fever and yellow fever) were reported in the at-risk areas for Rift Valley fever. These results show that the Rift Valley fever models may be useful for the forecasting and early detection of arbovirus outbreaks. Further progress is necessary in this area to refine models, but the use of predictive climatology for insect-borne diseases of animals should be encouraged.

While the precise impacts of epidemics are difficult to predict, the necessary public health response is clear. In such rapidly changing conditions, prevention is of the greatest importance; where prevention has failed, identifying and responding to epidemics becomes even more important.

OTHER PUBLIC HEALTH EMERGENCIES

The broad scope of the International Health Regulations (2005) allows for the inclusion of radionuclear and chemical events that have the potential to cause harm on a global scale. Such events, regardless of origin, rely on the same epidemiological principles of surveillance, early detection and response as biological threats in order to safeguard health.

Sudden chemical and radioactive events

For much of the world, life in the 21st century has become greatly dependent on chemical processing and nuclear power. Public health security in turn relies on the safety of these facilities and the appropriate use of their products. Major chemical spills, leaks and dumping, nuclear melt-downs, and the deliberate release of chemical or biological agents occupy yet another category of threats to public health security. The possibility of such events invokes the notion of surprise attack or accidents, innocent victims and malicious or negligent perpetrators, and causes fears that may be disproportionate to the real risk.

Most countries subscribe to international conventions banning chemical weapons. Incidents such as the release of sarin gas (the sole purpose of which is to harm the nervous system) on the Tokyo subway in 1995, however, remind us that although chemical and biological attacks are rare, there are individuals, groups and governments who are ready to use this brand of terrorism (see Box 2.2).

Similarly, chemical and nuclear processing plants operate under safety protocols, such as those outlined by the International Programme on Chemical Safety (*21*), to protect their workers, their facilities and the people and environment surrounding them. Nonetheless, human and mechanical errors occur and accidents happen, sometimes with devastating effects.

Wide-scale attacks using chemical weapons or major industrial accidents are not the full picture when it comes to the disease burden from chemical incidents. The majority of such deaths and illness is attributable to the many medium-sized and small-scale chemical incidents that take place every year around the world. Nevertheless,

Box 2.2 The deliberate use of chemical and biological agents to cause harm

Chemicals

The deliberate large-scale use of chemicals as poison gas weapons dates back to the First World War, when tear gas, mustard gas and phosgene were employed against troops in the trenches of European battlefields to deadly and disabling effect. Estimates range from about 1.17 to 1.25 million gas casualties on all sides, including between 85 000 and 91 000 fatalities, but exclude those who died from gas-related injuries years after the end of the war (16). The use of poison gas, including mustard gas, during warfare was prohibited by the Geneva Protocol of 1925 and the Chemical Weapons Convention of 1993, which also banned the development, production and stockpiling of such weapons.

The largest chemical weapons attack against a civilian population in modern times occurred in 1988, when Iraqi military forces repeatedly used mustard gas and other chemical agents against Kurds in northern Iraq. In the worst attack, on the Kurdish city of Halabja in March 1988, groups of aircraft flying many sorties repeatedly dropped chemical bombs. About 5000 people were killed and 65 000 others suffered severe skin and respiratory diseases and other consequences such birth defects and cancer (*17, 18*).

Biological agents

The potential of organisms used as weapons of biological warfare or bioterrorism was graphically illustrated, albeit unintentionally, by an accident involving anthrax in the former Soviet Union in 1979. The accident in Sverdlovsk, 1400 km east of Moscow, remains the largest documented outbreak of human inhalation anthrax. The number of people who died as a result has been estimated at between 45 and 100, among a total of up to 358 cases. In fatal cases, the interval between onset of symptoms and death averaged three days.

Attributed at first by government officials to the consumption of contaminated meat, it was later shown to have been caused by the accidental release of anthrax spores from a Soviet military microbiology facility. Epidemiological data revealed that most victims worked or lived in a narrow zone extending from the military facility to the southern city limit. Further south, livestock died of anthrax along the zone's extended axis. The zone paralleled the northerly wind that prevailed shortly before the outbreak. Antibiotics and vaccines were used to treat those affected and to bring the outbreak under control (*19, 20*).

Table 2.1 Examples of major chemical incidents (1974–2006)

Year	Location	Type of incident	Chemical(s) involved	Deaths	Injured	Evacuated
1974	Flixborough, United Kingdom	Chemical plant (explosion)	Cyclohexane	28	104	3000
1976	Seveso, Italy	Chemical plant (explosion)	Dioxin		193	226 000
1979	Novosibirsk, Russian Federation	Chemical plant (explosion)	Uncharacterized	300		
1981	Madrid, Spain	Foodstuff contamination (oil)	Uncharacterized	430	20 000	220 000
1982	Tacoa, Venezuela (Bolivarian Republic of)	Tank (explosion)	Fuel oil	153	20 000	40 000
1984	San Juanico, Mexico	Tank (explosion)	Liquified petroleum gas (LPG)	452	4248	200 000
1984	Bhopal, India	Chemical plant (leak)	Methyl isocyanate	2800	50 000	200 000
1992	Kwangju, Democratic People's Republic of Korea	Gas store (explosion)	LPG		163	20 000
1993	Bangkok, Thailand	Toy factory (fire)	Plastics	240	547	
1993	Remeios, Colombia	Spillage	Crude oil	430		
1996	Haiti	Poisoned medicine	Diethylene glycol	>60		
1998	Yaoundé, Cameroon	Transport accident	Petroleum products	220	130	
2000	Kinshasa, Democratic Republic of the Congo	Munitions depot (explosion)	Munitions	109	216	
2000	Enschede, Netherlands	Factory (explosion)	Fireworks	20	950	
2001	Toulouse, France	Factory (explosion)	Ammonium nitrate	30	>2500	
2002	Lagos, Nigeria	Munitions depot (explosion)	Munitions	1000		
2003	Gaoqiao, China	Gas well (release)	Hydrogen sulphide	240	9000	64 000
2005	Huaian, China	Truck (release)	Chlorine	27	300	10 000
2005	Graniteville, United States of America	Train tanker (release)	Chlorine	9	250	5400
2006	Abidjan, Côte d'Ivoire	Toxic waste	Hydrogen sulphide, mercaptans, sodium hydroxide	10	>100 000[a]	

[a] The number of consultations, not necessarily the number of people made directly ill.
Data source: (*22*). Data from 2000 onwards from the Major Hazard Incident Data Service (MHIDAS), Health and Safety Executive, London, United Kingdom, except for Goaqiao and Abidjan, which are from WHO.

it is from some of the larger scale incidents that the world has learned better how to prevent and respond to chemical and radioactive threats through industrial advances and diplomatic relations (see Table 2.1). Two major industrial accidents, a natural phenomenon and a forest fire are described below, all of which point to the necessity for a global response network for effective surveillance and early warning so as to mitigate the adverse effects of such occurrences.

Industrial accidents

One of the world's worst chemical accidents occurred around midnight on 2 December 1984, in the city of Bhopal in central India. A deadly cloud containing the toxic gas methyl isocyanate spilled from Union Carbide's large pesticide plant while most of the population of nearly 900 000 people were asleep (*23*).

The exact figures for the number of people killed and injured by the gas are disputed. According to official Indian figures, nearly 3000 people died in the first few hours of the accident, while hundreds of thousands were harmed, and more than 15 000 people have since died from cancer and other diseases (*23, 24*). Some estimates, however, have put the numbers much higher, suggesting that 10 000 people died initially and over 20 000 subsequently (*25*). Officially, it is estimated that about 120 000 people continue to suffer from chronic respiratory, ophthalmic, reproductive, endocrine, gastrointestinal, musculoskeletal, neurological and psychological disorders associated with the event. The release of gas also caused hundreds of thousands of people to flee the city and the polluted local environment.

The emergency and local health services were overwhelmed by the event at Bhopal. Lack of information about the identity of the gas, its health effects and the necessary clinical management and mitigation measures contributed to enormous health consequences. The acute industrial accident triggered a long-term crisis for the entire population of Bhopal, the Government of India and the industries involved. The health, economic and environmental consequences of the catastrophe are still being felt today.

Could a similar incident happen again? The answer is almost certainly yes. Chemical production and use has increased nearly tenfold worldwide over the last 30 years, and this is particularly true in developing countries (*26*). Several governments have learned from events such as Bhopal – and the accident at Seveso, Italy, where large amounts of dioxins were released into the environment in 1976 – and have introduced regulations to prevent and prepare for major chemical accidents. Poorer nations, however, are still struggling with a lack of technical capacity and regulatory infrastructure to ensure safe chemical management. In some countries with good technical capacity, the rapid pace of industrialization is outstripping the implementation of effective control measures. Increasing urbanization in such countries is exposing growing numbers of people to the risk of chemical incidents as they settle in close proximity to hazardous installations. This particularly affects the poorer segments of society who have little choice about where to live.

On 26 April 1986, explosions at reactor No. 4 of the nuclear power plant at Chernobyl in Ukraine, a republic of the former Soviet Union at that time, led to the release of huge amounts of radioactive materials into the atmosphere. These materials were deposited mainly over countries in Europe, but especially over large areas of Belarus, the Russian Federation and Ukraine. An estimated 350 000 clean-up workers or "liquidators" from the army, power plant staff, local police and fire services were initially involved in containing and cleaning up the radioactive debris during 1986–1987. About 240 000 liquidators received the highest radiation doses while conducting major mitigation activities within the 30 km zone around the reactor.

Later, the number of registered liquidators rose to 600 000, though only a small fraction of these were exposed to high levels of radiation. In the first half of 1986, 116 000 people were evacuated from the area surrounding the Chernobyl reactor to non-contaminated areas. Another 230 000 people were relocated in subsequent years. At the present time, about 5 million people live in areas of Belarus, the Russian Federation and Ukraine with levels of radioactive caesium deposition more than 37 kBq/m^2 (*27*). Among them, about 270 000 inhabitants continue to live in areas classified by their governments as strictly controlled zones, where radioactive caesium contamination exceeds 555 kBq/m^2.

In 2006, as the world marked the 20th anniversary of the Chernobyl accident, WHO released a report assessing the health impact of the worst civil nuclear accident in history (*27*). The report provided clear recommendations for future research directions and public health measures for national authorities of Belarus, the Russian Federation and Ukraine, the countries most affected by fall-out from the reactor explosion. More than 4000 thyroid cancer cases have been reported in these countries in children and adolescents for the period 1990–2002. This is significantly more than would be expected, yet precise estimates of risk are still unclear. Approximately 40% of these cases were detected through screening programmes and may otherwise have gone undetected (*27*). New thyroid cancer cases are likely to be reported in the coming decades.

The Chernobyl nuclear reactor stands empty after the 1986 explosions.

A child of Chernobyl is examined by medical staff after the accident.

The same report revealed that the most serious long-term public health impact is in the area of mental health (*27*). In addition to the lack of reliable information provided to people affected in the first few years after the accident, there was widespread mistrust of official information and the false attribution of most health problems to radiation exposure from Chernobyl. The necessary evacuation and relocation proved a deeply traumatic experience for many people: their social networks were disrupted and they had no possibility of returning to their homes. In addition, many had to face the social stigma associated with being an "exposed person"; this stigma continues and has led to increases in risk-taking behaviour, depression and other neurological and psychological disorders.

WHO recommends that both key professionals and the general public should be provided with accurate information about the health consequences of the Chernobyl disaster, as part of efforts to revitalize the affected areas. WHO continues its efforts to support improvements in health care for affected populations through the establishment of telemedicine and educational programmes, and by supporting research.

Natural phenomena

Chemical poisoning of large numbers of people caused by a natural event rather than an industrial accident occurred in August 1986, when about 1.6 million tons of CO_2 gas were suddenly expelled from Lake Nyos, in the North-West Province of Cameroon. This event was the result of a natural phenomenon that occurred when CO_2 gas on the bed of the lake was suddenly forced into the atmosphere as a result of a large landslide into the lake. Because CO_2 is heavier than air, the gaseous mass hugged the ground surface and descended valleys along the north side of the crater at about 50 km per hour. The thick cloud covered a distance of 20 km, suffocating up to 1800 people living in the villages of Nyos, Kam, Cha and Subum (*28*, *29*). Animals were also killed, including 3500 livestock.

Although a high number of casualties might seem unavoidable following such a sudden incident, measures can be put in place for prevention and preparedness to reduce risk and population vulnerability in the future. This can be done by learning lessons from natural disasters and providing sufficient resources and technical knowledge. Unfortunately, however, this is often not the case. Rare natural events are eventually forgotten or ignored and communities can face a recurrence without being prepared.

In the case of Lake Nyos and nearby Lake Monoun, which suffered a similar eruption in 1984, pipes have been installed to allow some of the CO_2 to be siphoned off. The danger of another expulsion of CO_2 remains, however, because there are still insufficient pipes to remove the gas completely. Moreover, communities have re-settled around the lakes. Understanding the potential triggers for a catastrophic expulsion of gas, recognizing the early warning signs, and having in place an alert system could all contribute to local populations being able to avoid a recurrence of the disaster.

Forest fires produce large amounts of biomass smoke containing a mixture of particulate matter and toxic and irritant gases such as carbon monoxide, formaldehyde, acrolein, benzene, nitrogen dioxide and ozone. Wood-smoke particulates can easily be transported over great distances (30). Such small particles bypass the normal body defence mechanisms and penetrate deep into the alveoli of the lungs, harming the respiratory system.

Transboundary air pollution with smoke took place in 1997–1998, when Indonesia suffered prolonged and uncontrolled forest fires causing a dense haze that spread as far as the Philippines, Singapore and parts of Malaysia, Thailand and Viet Nam, encompassing a population of over 200 million people. About 1 million hectares of forest, plantation and scrub land, chiefly in Sumatra and Kalimantan, burned continuously from July to October 1997. This devastating event was followed by further fires in early 1998.

There have been other large-scale forest fires in Indonesia both before and since, many of which have been shown to be caused by plantation companies clearing land for agricultural use by burning vegetation (*31*). In 1997, as in some other years, the spread of the fires had been facilitated by unusually dry conditions caused by El Niño Southern Oscillation. Moreover, logging activities had also made forests more vulnerable to fire – flammable debris is left behind and the opening up of the forest canopy allows more sunlight through to dry out the forest floor.

The resulting smoke haze adversely affected the health of populations in Indonesia and neighbouring countries, causing an increase in the incidence of bronchial asthma, acute respiratory infection and conjunctivitis. In Indonesia, among the 12 360 000 people exposed to the haze, it was estimated that there were over 1 800 000 cases of bronchial asthma, bronchitis and acute respiratory infection (*32*). Health surveillance in Singapore from August to November 1997 showed a 30% increase in hospital outpatient attendance for haze-related conditions, as well as an increase in accident and emergency attendances (*33*). A study in Malaysia found significant increases in respiratory hospitalizations related to the haze, specifically those for chronic obstructive pulmonary disease and asthma. The most vulnerable group was people over the age of 65 (*34*). The long-term effects on health from exposure to the haze are yet to be determined.

Causes of acute threats to public health security include those outlined for infectious diseases, acute events that occur after war or natural disasters, and chemical or nuclear events. This chapter has provided examples of many of these causes and the consequences as seen during the last century.

Chapter 3 describes more recent events in the 21st century and increases our understanding of why border controls and international agreements are not enough – there must be strong national surveillance and response mechanisms to detect and respond to threats where and when they occur, together with global mechanisms to detect and respond should they become threats to global public health security.

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