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Environmental and Occupational Health

Learning Objectives

Upon completion of this chapter, the student should be able to:

1. Recognize and describe environmental health hazards;
2. Recognize and describe work-related disease and injury;
3. Formulate strategies for their prevention;
4. Recognize and describe the interaction between environmental and occupational exposure on health of the community.

ENVIRONMENTAL HEALTH

INTRODUCTION

Environmental challenges are receiving a growing level of public, private, and governmental attention. This varies from recognition of the vital importance of safe water, through waste disposal (nuclear, medical, industrial, household) and sewage disposal, to global climate change. The direct health effects of poor sanitation are horrendous in the cost to lives and health. Although progress is being made, high levels of danger to rural populations remain, especially in sub-Saharan Africa. In the industrialized countries, the sanitary revolution of the nineteenth century was a fundamental achievement of public health, resulting in a doubling of life expectancy.

The dramatic challenges of environmental degradation have come more into focus in the twenty-first century and the issues are by no means resolved. Public concern over environmental issues is higher than in previous decades. While the application of environmentally friendly policies is improving in many countries, it is still not an issue where reduced standards of living are an acceptable part of the solution, and technical solutions are slow in coming to substantive fruition. The international and national political levels address the environment in positive terms with many targets for action but progress remains slower and less comprehensive than the challenge requires. The United Nations Environment Programme (UNEP) defined themes and issues for the twenty-first century as shown in [Box 9.1](#).

Of the eight Millennium Development Goals (MDGs) adopted by the United Nations (UN) in 2001 and accepted by virtually all member countries, one is: “to ensure

environmental sustainability”, with the following specific targets:

- *Target 9* – Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources.
- *Target 10* – Reduce by half the proportion of people without sustainable access to safe drinking water.
- *Target 11* – Achieve significant improvement in lives of at least 100 million slum dwellers by 2020 (UNDP, 2008).

The MDGs call for international cooperation to prevent environmental degradation resulting in global warming. Progress in MDGs in terms of drinking water and sanitation is shown in [Box 9.2](#).

A safe environment is fundamental to health; clean water is as important as shelter and food in a hierarchy of health and survival needs. Access to safe water has increased, but globally 19 percent of the burden of disease among children aged 0–1 years is from diarrheal disease largely due to contaminated water, while 10 percent is due to malaria and another 10 percent to malnutrition, intestinal infestation, and childhood disease clusters all related to poor environmental conditions.

Overshadowing other environmental issues are climate change and global warming as a result of both natural and human-caused phenomena. The result could be massive threats to public health through the spread of diseases related to climate, such as malaria and cholera with flooding and stagnant waters, desertification of highly vulnerable zones of the world, and disruption of safe drinking water and food supplies. Wide-scale natural disaster phenomena of rising sea levels with permanent flooding of coastal areas, hurricanes, and ecological changes of unpredictable severity are anticipated. A wide consensus of scientific opinion raises the level of concern over such disastrous effects such that governments and the public seem to be ready to act to reduce fossil fuel consumption and other root causes of greenhouse gases.

Safe water supplies and waste management are fundamental and still problematic aspects of public health and community hygiene. Incidences of contamination by biological, chemical, physical, or other disease-causing agents in the external environment and the workplace are major public health and political concerns of the twenty-first century. Since the 1960s, a high degree of consciousness has developed regarding these problems. Air, water, ground,

BOX 9.1 The 21 Emerging Issues in Environmental Health

Cross-cutting Issues

- 1 Governance aligned with the challenges of global sustainability
- 2 Global environmental challenges and moving towards a green economy
- 3 Reconnecting science and policy
- 4 Catalyzing rapid and transformative changes in human behaviour towards the environment
- 5 Coping with creeping changes and imminent thresholds
- 6 Migration caused by new aspects of environmental change

Food, Biodiversity, and Land Issues

- 7 Ensuring food safety and food security for 9 billion people
- 8 Integrating biodiversity across the environmental and economic agendas
- 9 Boosting urban sustainability and resilience
- 10 New rush for land: responding to new national and international pressures

Freshwater and Marine Issues

- 11 Water–land interactions: shift in the management paradigm?
- 12 Degradation of inland waters in developing countries
- 13 Potential collapse of oceanic systems requires integrated ocean governance
- 14 Coastal ecosystems: addressing increasing pressures with adaptive governance

Climate Change Issues

- 15 Climate change mitigation and adaptation: managing the unintended consequences
- 16 Changing frequency of extreme events
- 17 Managing the impacts of glacier retreat

Energy, Technology, and Waste Issues

- 18 Accelerating implementation of environmentally friendly renewable energy systems
- 19 Minimizing risks of novel technologies and chemicals
- 20 Solving the impending scarcity of strategic minerals and avoiding electronic waste
- 21 Environmental consequences of decommissioning nuclear reactors

Source: United Nations Environment Programme. *21 Issues for the 21st century: results of the UNEP foresight process on emerging environmental issues*. Nairobi: UNEP; 2012. Available at: http://www.unep.org/publications/ebooks/foresightreport/Portals/24175/pdfs/Foresight_Report-21_Issues_for_the_21st_Century.pdf [Accessed 15 August 2012].

and workplace pollution are issues of concern to the public, the business sector, the media, and governmental and non-governmental organizations, and are part of the general culture of our times. The growth of the concepts of right-to-know, consumerism, and advocacy in public health has led to greater sensitivity to these issues in many countries.

BOX 9.2 Progress Towards the Millennium Development Goal on Drinking Water and Sanitation, 2012

Safe water and sanitation is vital to improving health and well-being. The 2001–2015 Millennium Development Goals (MDGs) set a target (7C) of reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation.

The MDG progress monitoring report by the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2012 states that the drinking water target for sustainable access to safe drinking water between 1990 and 2015 was met in 2010, 5 years ahead of schedule.

The 2012 report indicates that more than 2 billion people have gained access to improved drinking water sources since 1990, but there are challenges of great disparities, with 780 million people remaining without access to improved drinking water sources and 2.5 billion lacking improved sanitation. Sub-Saharan Africa lags behind in this measure for rural dwellers and the urban poor in particular, with the burden of poor water supply mostly falling on girls and women.

Nevertheless, the global achievement indicates commitment of government leaders, public and private sector entities, communities and individuals. The international community (UN Rapporteur on Human Rights to Water and Sanitation) will maintain its surveillance on water and sanitation even following the 2015 MDG target date.

Source: World Health Organization/United Nations Children's Fund. *Progress on drinking water and sanitation: 2012 update*. Geneva: WHO/UNICEF; 2012. Available at: <http://www.unicef.org/media/files/JMPreport2012.pdf> [Accessed 16 August 2012].

Occupational health developed as a separate area of concern from environmental health, but in recent years there has been an increasing recognition of the interaction between workplace and community health hazards such as in asbestos and cancer. Occupational health is included as the second part of this chapter because of common advocacy, professionalism, technology, and regulatory approaches. The level of public response to environmental threats is illustrated by the groundswell of public opinion against environmental decay.

Issues have become more complex and go beyond the prevention of disease and traditional public health. While the resources needed to reduce the environmental neglect from inadequate sanitation and high levels of pollutants in the air, water, and soil are costly, the burden to society of environmental decay can be even greater in the long term.

Twentieth-century advocacy groups and reformers have made major contributions to public policy, which are akin to the achievements of their predecessor reformers of the eighteenth and nineteenth centuries in the areas of abolition of slavery, humane treatment of prisoners and the mentally ill, improvements in working conditions in factories and mines, and public health sanitary improvements (see Chapter 1).

Globalization, industrialization, and fossil fuel dependency have become an accelerated threat to the global environment. Not only the scientific community, but also governments, the business community, and the general public, are increasingly accepting that human society must order its affairs so that its use of natural resources does not deplete or overwhelm the self-sustaining capacity or natural regenerative powers of the environment. Environmental health is a central issue in the New Public Health in that it is the root cause of much disease and death that is preventable and degrades the environment with irreversible loss to society.

GLOBAL ENVIRONMENTAL ISSUES

A World Summit on Sustainable Development called for world leaders: “aiming to achieve by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment”. Specific recommendations for both technical and financial assistance will be needed for developing countries and economies in transition to build their capacity (Johannesburg, 2002).

The US Institute of Medicine in 2007 called for cooperative participation of industry in “green chemistry” and voluntary compliance both at home and internationally, eliminating double standards in industrialized and developing countries, and complying with a robust regulatory environment to achieve less industrial, air, and global environmental pollution (Harrison and Coussens, 2007).

The *World Health Report 2007* addressed the threats of increasing risk of disease epidemics, industrial accidents, natural disasters, and other health emergencies and their effects on global public health security. The International Health Regulations of 1995 (see Chapter 16) were an important asset to the process of international collaboration to identify risks and act to contain them. Pandemics of severe acute respiratory syndrome (SARS) and influenza H1N1 showed the dangers of spread of disease from animals and birds to humans and then their spread to distant parts of the world within hours. At the same time, natural disasters and human-caused catastrophes revealed both the potential and weaknesses of international cooperation to protect the public health.

International consensus on global warming has called for action to raise awareness, wide-scale preventive measures, and preparedness for the consequences of global climate change. Reviews by international agencies have confirmed the warnings and call for coordinated international and local action (Box 9.3). These warnings are associated with projections of attributable and avoidable burdens of disease associated with environmental degradation, global warming, and associated climate changes. The continuing struggle to reduce climate-damaging practices is meeting strong economic and political resistance, but progress is being made on

BOX 9.3 Global Environmental Challenges and Health Impact

- Global warming/climate instability
- Air pollution/carbon dioxide emissions with atmosphere/ozone depletion
- High population growth in low-income countries
- Inequalities between industrial and non-industrial countries
- Social, economic, and political inequalities nationally and internationally
- Deforestation/forest clearing and biodiversity loss
- Drought/flooding – lack of safe water/water shortage – management and technological advances
- Rural poverty, conservative agriculture and animal husbandry – food insecurity, passage of infectious diseases from animals to humans
- Food production, prices increase, poor food security – distribution and improved production methods
- Energy and resource depletion – search for alternative cost-effective energy sources
- Soil erosion/pesticide pollution/desertification – regional famine, migration, refugees
- Chemical/toxic wastes – long-term carcinogenic and teratogenic effects
- Wars and civil strife/terrorism/incitement and genocide/nuclear threats/armament costs
- Economic growth and economic decline
- Disease emergence and transference from local habitats to world exposure – HIV, SARS, West Nile fever, Lyme disease, Rift Valley fever, Lassa fever

Sources: World Health Organization. *The world health report 2007 – a safer future: global public health security in the 21st century*. Geneva: WHO; 2007. Available at: <http://www.who.int/whr/2007/en/> [Accessed 17 August 2012].

Corvalin C, Hales S, McMichael A. *Ecosystems and human wellbeing: health synthesis: a report of the millennium ecosystem assessment. Health impacts of ecosystem impairment due to environmental changes*. Geneva: WHO; 2005. Available at: <http://www.who.int/globalchange/ecosystems/ecosys.pdf> [Accessed 15 August 2012].

United Nations Environment Programme. *21 Issues for the 21st century: results of the UNEP foresight process on emerging environmental issues*. Nairobi: UNEP; 2012. Available at: http://www.unep.org/publications/ebooks/foresightreport/Portals/24175/pdfs/Foresight_Report21_Issues_for_the_21st_Century.pdf [Accessed 15 August 2012].

specific issues and technological advances such as in water and wastewater management, and searches for cost-effective energy sources. A vast complex of environmental issues having major health impacts is shown in Box 9.3.

The environment and human society interact and are mutually dependent. The ecological issues that face the world include those that can be addressed locally and nationally and others that require concerted international cooperation. Local action is part of global responsibility. Local issues require close cooperation among different agencies of government at all levels, with local authorities, supported at state and national levels. Non-governmental organizations (NGOs), the media, the private sector, and

voluntary groups all have important roles in promotion of a healthful environment. Unrestrained population growth and rising standards of living in many developing countries with attendant demand for consumption standards of developed countries undermine local and international efforts to maintain a balance between nature and human society. At the same time, the industrialized countries are beginning efforts to reduce polluting standards, but the time available to prevent runaway global warming is very short.

Global society must face simultaneously those environmental, social, and health issues that relate to poverty and high population growth in the poorest countries. Urbanization, demographic, and epidemiological shifts are associated with growing populations with health needs related to long-term diseases and conditions. These can be aggravated by environmental pollution, which presents a severe challenge in rapidly developing societies with urban crowding, air and other pollution, and fossil fuel issues. Increasing consumption associated with increasing per capita incomes creates demands for increased food supply that will be difficult to meet. Agricultural reform with improved water management and smallholder methods including better transportation, marketing, and wider use of genetically modified foods will be essential to meet these demands. Such demands are occurring in an environment of decreasing water supply, uncertainty as to climate effects, and the continuing struggle to lift people from poverty and its adverse health effects. Some successes are impressive, with many mid-level income countries achieving better education and health, whereas in some newly wealthy countries the rapid increases in productivity and income coexist with large sectors of the population remaining in rural poverty and decay.

Among the long-range issues confronting many countries are water supplies and their quality, which are endangered by overuse and the pollution of groundwater sources. Air and soil pollution, deforestation, and desertification require local, national, and international multisectoral cooperative planning and intervention. Water alone will become a cause of technological change and possible conflict between countries. At present, nearly 700 million people suffer from water shortage, and recurrent droughts are expected to spread with global warming to affect global food supplies and prices, pushing more people into moderate and severe food insecurity.

Public consciousness regarding these issues has increased during the past several decades. Environmental concern has become an essential part of accepted public philosophy in many developed countries. Its place in developing countries is often of low priority, coming after the struggle to expand economically as well as the severe problems of population growth and basic services. Economic growth and health status are closely related to agriculture, food supplies, and distribution systems, as well as preservation of agricultural land and rational use of energy. As was the case in numerous

countries during their industrial development and urbanization, many Eastern European countries prioritized industrialization over all other issues and subordinated environmental concerns, so that accumulated environmental degradation is part of the long-range burden of post-Soviet societies.

GEOGRAPHIC AND ENVIRONMENTAL EPIDEMIOLOGY

Geographic epidemiology is defined as the description of spatial patterns of disease incidence and mortality. It is part of descriptive epidemiology that generally describes the occurrence of disease according to demographic characteristics of the population at risk and in terms of place and time. Snow's description of cholera in London in 1854 and many other observational studies supported hypotheses that turned out in practice to be the case, even though the direct causal relationships were not demonstrable at the time.

Geographic epidemiology helps to generate hypotheses that can then be tested by rigorous methods. Environmental and occupational epidemiology applies a wide range of research methods to the study of disease in relation to environmental or work-related conditions. In practical everyday public health, the findings of a common point source of disease, injury, or death may lead directly to contaminated water, toxic exposure at a worksite, a risk condition, or polluted air of a city. While these may need case-control or other more formal studies for confirmation, the findings of known risk factors on routine surveillance should be sufficient to lead to adequate public health intervention by the appropriate regulatory authorities.

Epidemiological studies may describe in quantitative terms the relationship between the frequency of disease and the degree of exposure to a particular agent. Such studies are subject to errors in the measurement of exposure. Measurement of exposure by place of residence or work is only an approximation. Moreover, within the same community there will be wide variation in actual exposure levels to the toxic agent. The agent may affect different populations or subgroups differently. There may be genetic and social factors at play as well. In cases where there is a long time lapse between exposure and resultant disease, and many independent variables, it may be very difficult to attribute the disease to a specific exposure, as in the case of asbestos exposure and mesothelioma. The risk of asbestos exposure was compounded by cigarette smoking, affecting the workers directly exposed. But asbestos also affected the families of workers, as well as people in the community secondarily exposed to inhalation of the carcinogenic fibers, with residual asbestos material having been discarded or still present in roofing and many other applications. The cumulative evidence established the causal relationship and justified action to eliminate asbestos use in work settings and the wider environment.

TABLE 9.1 World Health Organization Environmental Burden of Disease: Health Targets and Issues

Target	Issues
Multisectoral policies to protect the environment	Coordination between agencies at international, national, regional, and local levels
Raising public awareness of global climate and the health effects of environmental health	Promotion of public/private consortia for environmentally friendly policies to reduce greenhouse effects, and promote alternative fuels, chemicals, construction, agriculture policies
Monitoring and control mechanisms for environmental hazards	Chemicals, ionizing radiation, noise, biological agents, consumer goods, risk assessment
Adequate supplies of safe drinking water	Quantity, quality of water; international, national programs, ground and surface water surveillance, quality control; water management standards
Protection against air pollution	Legislative administrative and technical measures to control indoor and outdoor pollution
Reduced risk of food contamination including harmful additives	Legislative administrative and technical measures to control food contamination and additives, and production, storage, transport, sale, and use
Eliminate risks of hazardous wastes	Effective legislative, administrative, and technical measures for surveillance and control of dumped wastes
Healthy and safe urban environment	Housing and urban planning standards, waste disposal, potable water supply, recreation, open spaces, traffic control, waste disposal, and sanitation
Protection against work-related risks	Protection against biological, chemical, physical hazards; worker education, industry self-monitoring and government regulation

Source: Campbell-Lendrum D, Woodruff R. Climate change: quantifying the health impact at national and local levels. Prüss-Üstün A, Corvalán C, editors. Geneva: WHO; 2007. Available at: http://whqlibdoc.who.int/publications/2007/9789241595674_eng.pdf [Accessed 15 August 2012].

ENVIRONMENTAL TARGETS

In 1962, publication of Rachel Carson's *Silent Spring* on the environmental effects of indiscriminate use of pesticides was a signal event galvanizing public opinion in the USA and elsewhere. The US Environmental Protection Agency (EPA) was established by President Nixon in 1970 in response to a growing public concern over environment issues. The EPA mandate was given broadly: "To declare a national policy which will encourage productive and enjoyable harmony between man and his environment", "To promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man", and "To enrich our understanding of the ecological systems and natural resources important to the Nation".

The World Health Organization (WHO) *Commission on Health and Environment Report* (1992) developed a consensus documentation of international environmental health issues. This commission, chaired by Simone Weil of the European Parliament, included many distinguished scientists, professional leaders, and international organizations. The report represented a strong international consensus on joint action to prevent and clean up environmental degradation that had occurred in Europe over several decades. The European Region of the WHO consensus statements on health targets that emerged represented a broad societal commitment to stop environmental degradation. These have been reissued in various forms and increasingly represent a wide commitment to action to slow global warming, as this

has become the center-stage issue of environmental health in recent years.

The WHO (2006) defines the environment, in relation to health, as: "all the physical, chemical, and biological factors external to a person, and all the related behaviors"; "Environmental health consists of preventing or controlling disease, injury, and disability, related to the interactions between people and their environment" (Healthy People 2020; Last, 2001).

Public health has traditionally placed high priority on sanitation, housing, and urban planning in the battle to reduce the burden of infectious disease. The sanitary movement of the nineteenth century had an enormous impact on the control of communicable diseases. In the twenty-first century, environmental health issues are still an enormous challenge for public health and society in general (Table 9.1).

The Centers for Disease Control and Prevention (CDC) in the USA declared advances in public health organization, infectious disease control, and occupational health as being among the Ten Great Achievements of Public Health in the USA in the twentieth century (CDC 1999, 2011). The US Healthy People 2020 vision for environmental health in the USA includes six theme topics:

- outdoor air quality
- surface and ground water quality
- toxic substances and hazardous wastes
- homes and communities
- infrastructure and surveillance
- global environmental health.

Over the years, the EPA has addressed many specific issues setting national standards in the field. In 2012, the EPA focused on:

- air
- water
- green living
- health and safety
- land and cleanup
- pesticides, chemicals, toxics
- waste
- water issues.

In 2012, the EPA issued new regulations on fuel economy standards, pollution from power plants, and renewable fuels (EPA 2012), which provide hope for significant reductions in pollution in urban areas in the USA.

ENVIRONMENT AND INFECTIOUS DISEASES

Climate and environmental change can have important impacts on infectious disease. Diseases such as dengue, Lyme disease, West Nile fever, chikungunya, and Legionnaire's disease can move from their original sources to become endemic in new locations as environmental and vector conditions change.

The lessons learned in swamp and still-water drainage, disinfection of potable water supplies, and treatment of solid and liquid wastes are still not applied universally by either the less developed countries or middle-level developing and industrialized countries. The threat of local, national, and international disasters, including the re-emergence of cholera in South America and Russia and *Giardia* as a major outbreak in the USA, have returned the classic issues of water quality to center stage in modern public health. Plague broke out in India in 1994 and Rift Valley fever struck Egypt in 1977 and later affected various parts of the Middle East (Saudi Arabia, Yemen), where it is now likely to be endemic.

The resurgence of malaria and dengue fever in large parts of the world highlights the problems of vector control and damaging effects of environmental degradation on the burden of disease in modern public health. The USA experienced its biggest spike in human cases of West Nile virus since 2003, with 5,674 cases of the disease reported nationwide in 2012, including 286 deaths (up to 31 December 2012). Infections were reported in people, birds, or mosquitoes in 48 US states, 62 percent of these in California, Louisiana, Michigan, Mississippi, Oklahoma, South Dakota, and Texas. CDC (2013) stated that one-third of the total cases were in Texas.

Lyme disease (Box 9.4) exemplifies another vectorborne disease, representing an important and current public health problem affecting populations and substantially burdening health departments. In the 1990s, West Nile fever appeared

BOX 9.4 Lyme Disease

Lyme disease, which results from the bite of an infected blacklegged tick, is an example of a vectorborne disease caused by the bacterium *Borrelia burgdorferi*. Humans who acquire the disease are likely to experience a fever, headache, and a distinctive pink/red circular skin rash surrounding the area of the bite. The rash typically develops 3–30 days following the tick bite, and soon afterwards fatigue and other flu-like symptoms ensue. If untreated, symptoms worsen in severity and the infection may progress, affecting the joints, heart, and nervous system. This may include temporary paralysis of facial muscles.

The most common vectorborne disease in the USA, there are an estimated 20,000 new cases of Lyme disease documented annually. In 1991 Lyme disease grew to become nationally recognized in the USA. Since then, cases documented per year have more than doubled. Improved laboratory techniques may play a role in the increase in reported cases, but there appears to be a true rise in Lyme disease incidence. The UK Health Protection Agency (HPA) estimates that there are 2000–3000 cases of Lyme disease in England and Wales each year and, furthermore, the disease occurs widely in northern Europe and Asia.

In the USA, most cases are concentrated in north-eastern, mid-Atlantic, and north-central regions and mainly affect the age groups 5–14 and 45–54 years. The CDC established 10 reference states where the disease is endemic for surveillance purposes; of approximately 64,000 cases of Lyme disease between 2003 and 2005, 93 percent were from these 10 states. Between 2003 and 2005, the average yearly rate in these states was 29.2 cases per 100,000 population. The Healthy People 2010 objective was to lower the yearly incidence to 9.2 cases per 100,000 population, one-third of the current rate.

Prevention requires safety precautions: avoiding regions in which ticks are highly concentrated, applying insect repellents and carrying out body examinations and removal of ticks within the first 24 hours of attachment are strategies that aid in lowering the chances of bacterial transmission to the person. Landscaping maneuvers can substantially reduce the infestation of ticks in certain regions for people living in high-risk woodland areas. Antibiotics are used in treatment and various vaccines have been developed.

Sources: Centers for Disease Control and Prevention. Lyme disease, United States 2003–2005. *MMWR Morb Mortal Wkly Rep* 2007;56:573–6. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5623a1.htm> [Accessed 15 August 2012].

National Health Service. Lyme disease [updated 15 August 2011]. UK: NHS. Available at: <http://www.nhs.uk/Conditions/Lyme-disease/Pages/Introduction.aspx> [Accessed 15 August 2012].

for the first time in the north-east USA and it is now endemic in many parts of the USA. In 2003, SARS was spread from China to Toronto, causing the city to be placed under virtual quarantine. Chikungunya fever appeared in France and Italy in 2007, and in Hong Kong in 2008, brought by travelers from Asia. Spread by *Aedes albopictus* and *Aedes aegypti*

mosquitoes, which are common in many parts of Western and Central Europe, chikungunya is a viral disease characterized by fever, severe joint pain, nausea, muscle pain, and rash, often of sudden onset. Typically, the joint pain lasts for a few days or weeks, during which time the pain is severe and incapacitating. Most cases recover, but some individuals experience long-lasting joint pain or eye, neurological, or heart complications, which severely debilitate a patient. In regions where dengue is endemic, chikungunya is often misdiagnosed for dengue owing to their similar clinical manifestations. Infected female mosquitoes bites cause human-to-human virus transmission, with risk linked to the distance between mosquito breeding areas and human habitation. Preventive efforts focus on environmental measures to minimize breeding areas and control measures include the use of insecticides, repellents, protective clothing, and insecticide-impregnated mosquito bed nets.

The concept of environmental health has been widened in recent decades by the spectrum of global changes to the environment as a result of environmental pollution by humans and natural events such as volcanic eruptions. The greenhouse effect is the warming of the global environment through retention of solar heating of the Earth by increasing the greenhouse gases in the Earth's surrounding atmosphere. Disposal of toxic and radiological waste constitutes a very difficult public health challenge in many countries. Land degradation, loss of topsoil, deforestation, groundwater depletion, and acidification of water and soil are all challenges in environmental health in the twenty-first century. The effects of global environmental changes cannot be predicted with certainty, but there is scientific consensus on the serious and imminent dangers to the environment and human society which require both global and local preventive action and public health crisis response capacities.

Poverty, low levels of education, and rapid population growth in the poorest countries with limited food production potential stand in contrast to high levels of consumption and energy use and low rates of population growth in the industrialized countries. Many environmental issues involve more than one country, partly because of the transportation of waste products or hazardous materials from one country to another, by wind, water, or deliberately by people. Economic concerns include the destruction of fishing stocks, damage to forests, and more global concerns of ozone depletion, global warming, and ocean pollution. Intersectoral cooperation within a country, and international cooperation and regulation to reduce pollution of common waters in seas, lakes, and rivers shared by more than one country are part of a broad New Public Health agenda.

Global Climate Change

There is widespread consensus that the warming of the Earth is a result of human activities. It is an emerging risk factor

for health, the spread of infectious diseases, and disruption of food and freshwater supplies. The effects of global warming are expected to include serious weather disruptions and changes in ecology that could threaten plant, human, and other animal life on Earth. The policy-making uses of estimates of health impacts include the identification of groups at risk for specific diseases and the use of scarce resources, which help to target measures needed for controlling the emissions of greenhouse gases.

The Human Development Report of 2007/2008 saw climate change as the defining human development challenge of the twenty-first century. The more recent Human Development Report in 2013 highlights the importance of sustainability and equity, two imperative elements strongly intertwined within the issue of climate change. Failure to respond to this challenge will stall and reverse international efforts to reduce poverty. The poorest countries and most vulnerable people will suffer the most damaging setbacks, but no country will be immune to the impact of global warming.

The 2013 Human Development Report indicates that it is impossible for the extraordinary advances made in human development to continue unless major steps are taken to diminish environmental risks and inequality. Increased exposure to droughts, floods, and storms is already destroying opportunity and reinforcing inequality. Overwhelming scientific evidence indicates that the world is moving towards the point of irreversible ecological catastrophe. Avoiding the impact of the most damaging climate changes requires global action in the decades ahead. The financial resources and technological capabilities exist, but implementation requires a sense of urgency, public interest, and political will to make deep cuts in greenhouse gas emissions. Achievement of MDG7 (to ensure environmental sustainability) rests very much on addressing the issues of global warming.

The WHO highlights major global environmental dangers that impact life globally. These effects include climate change, ozone depletion, reduction in biodiversity resulting in changes in ecosystems, land degradation, and pressure and strain on food-generating systems. [Figure 9.1](#) provides examples of health effects emerging from major environmental and ecosystem changes. Severe droughts and prairie fires in Russia and Ukraine during 2011 and across North America in 2012 have had a serious impact on global production of corn and grain, almost immediate effects on food supply and prices, and an especially harsh impact on poor countries and poor people in rich countries.

An increasingly warmer climate warns us of the possibility of devastating consequences, including increased air pollution, more disease transmission via unsafe, unclean water and contaminated food, more natural disasters, and extreme weather conditions. Furthermore, agriculture and crops are likely to be affected. Of particular importance to

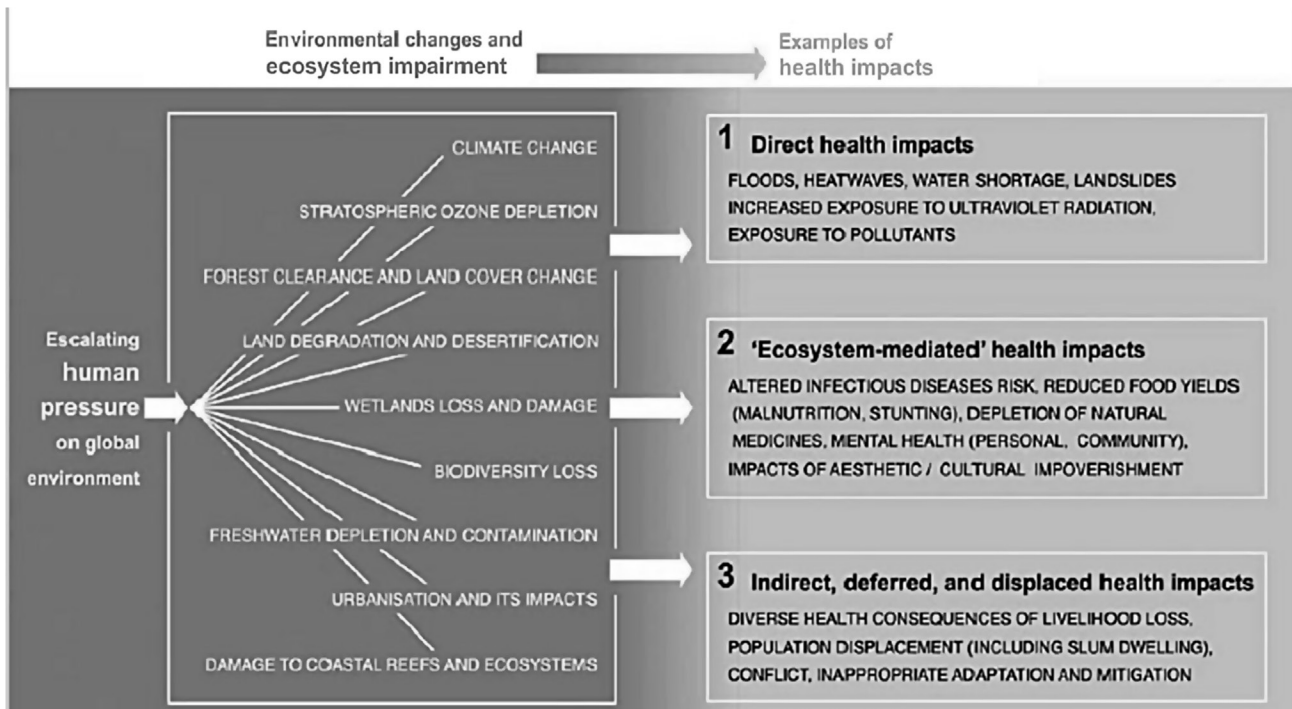


FIGURE 9.1 Environmental change, ecosystem effects, and human health. Source: Corvalin C, Hales S, McMichael A. *Ecosystems and human wellbeing: health synthesis: a report of the Millennium Ecosystem Assessment*. Health impacts of ecosystem impairment due to environmental changes. Geneva: WHO; 2005. Available at: <http://www.who.int/globalchange/ecosystems/ecosys.pdf> [Accessed 15 August 2012].

underdeveloped countries, climate change may bring about problems related to the containment and control of infectious diseases. Major causes of mortality, such as malaria, cholera, diarrheal diseases, dengue fever and other vector-borne diseases, are extremely sensitive to climate and influenced by temperature, humidity, and rainfall.

A special risk with regard to climate change is the effect on coastal populations worldwide of rising sea levels due to melting polar ice caps. The melting of taiga and tundra may release trapped methane gas in enormous quantities, further exacerbating global warming. Nearly 60 percent of the global population and 50 percent of the US population live in coastal counties.

Climate change is demonstrated through the elevation in global average air and ocean temperatures, the extensive melting of ice and glaciers, and a rise in sea levels. The World Meteorological Organization has annual updates on the status of climate change and greenhouse gas emissions (Box 9.5). There are documented changes in the frequency and degree of extreme weather conditions including hurricanes, heavy rainfall and flooding, forest fires, and heatwaves, all of which can create public health emergencies.

In situations of extreme weather, deaths resulting from cardiovascular or respiratory disease can be attributable to heatwaves. Heatwaves can cause high numbers of deaths among the elderly in particular, such as occurred in Chicago in 1995 with an estimated 700 deaths, and a 2003 heatwave in Europe which caused an estimated 50,000 deaths.

Floods, droughts, and unclean water increase the risk of disease, and when freshwater is unavailable, proper hygiene is seriously jeopardized. These devastating events cause serious damage to homes, communities, and much needed health facilities. These situations can be associated with cholera and other diarrheal diseases, such as occurred in Haiti in recent years (see Chapter 10).

Pre-existing medical conditions or malnutrition, a long-term contributor to high mortality in developing countries, may be worsened with widespread problems due to climate change affecting crop harvests. The WHO and the majority of scientists and environmental activists view climate change as a threat to the basic needs and primary determinants of health: air, water, food, shelter, and freedom from disease. The dramatic consequences of climate change underscore the need for international standards and cooperation to change the way in which we use energy and the way in which we live our daily lives.

Environmental Impact on Health Burden of Disease

Environmental hazards contribute to a wide range of diseases. The WHO reports that as much as 25 percent the burden of disease worldwide is from preventable environmental exposures, including more than 13 million deaths annually and nearly one-third of mortality and morbidity in low-income countries. Environmental factors are responsible for more

BOX 9.5 Climate Change

The World Meteorological Organization annual updates on the status of climate change and greenhouse gas emissions indicate that the decade 2001–2010 was the warmest on record since 1880, in terms of average global temperatures. These warmer temperatures surpassed the previous record decade, 1991–2000.

In 2008, the latest year for which data are available at the time of writing, global carbon dioxide emissions continued to rise, reaching 30.1 billion tonnes, an increase of 1.7 percent from the previous year. This change was smaller than in the period 2006–2007 (2.9 percent) owing to the economic crisis.

The December 2010 UN Climate Change Conference in Cancún, Mexico, was a step forward in international negotiations under the UN Framework Convention on Climate Change. A set of decisions known as the "Cancun Agreements" was adopted by the international community to address collectively and comprehensively the long-term challenges of climate change with a global drive of national actions to mitigate greenhouse gas emissions.

The Montreal Protocol for international reduction in ozone-depleting substances is a success story in protection of the ozone layer. At the end of 2009, the consumption of 98 percent of all ozone-depleting substances controlled under the listed in this Protocol had been phased out.

Biodiversity of the world's forests remains imperiled by the still high rate of global deforestation and forest degradation as well as a decline in primary forests. The problem remains, however, the rate of deforestation, and loss of forest from natural causes is slowing down.

Sources: *Climate change and human health: global environmental change* [updated 2012]. Geneva: WHO. Available at: <http://www.who.int/globalchange/environment/en/> [Accessed 15 August 2012].
United Nations Development Programme. *Human Development Report 2011, sustainability and equity: a better future for all*. New York: UNDP; 2011. Available at: <http://hdr.undp.org/en/reports/global/hdr2011/download/> [Accessed 11 August 2012].
World Health Organization. *Protecting health from climate change: connecting science, policy and people*. Geneva: WHO; 2009. Available at: http://whqlibdoc.who.int/publications/2009/9789241598880_eng.pdf [Accessed 2 August 2012].

than 33 percent of illness in children under 5 worldwide and as many as 4 million lives in this age group could be saved, mostly in developing countries, by preventive environmental measures. Safe household water storage and hygienic measures, cleaner and safer fuels, better built environment, less air pollution, better home and workplace management and use of toxic substances, and better water resource management would reduce diseases such as diarrhea, respiratory infections, malaria, dengue and West Nile Fever virus (Table 9.1). Knowledge regarding disinfection of drinking water supplies and treatment of solid and liquid wastes is not always applied, either in the less developed countries or in middle-level developing and industrialized countries (Box 9.6).

Environmental factors affect the developing countries most, as they suffer from poor water supplies, low levels

BOX 9.6 Preventing Disease Through Healthy Environments

- Environmental hazards are responsible for about a quarter of the total burden of disease globally, and as much as 30 percent in regions such as sub-Saharan Africa. Worldwide, 13 million deaths could be prevented every year by making our environments healthier.
- In children under the age of five, one-third of all disease is caused by environmental factors such as unsafe water and air pollution.
- Every year, the lives of 4 million children under 5 years, mostly in developing countries, could be saved by preventing environmental risks such as unsafe water and polluted air.
- In developing countries, the main environmentally caused diseases are diarrheal disease, lower respiratory infections, unintentional injuries, and malaria.
- Better environmental management could prevent 40 percent of deaths from malaria, 41 percent of deaths from lower respiratory infections, and 94 percent of deaths from diarrheal disease – three of the world's biggest childhood killers.
- In the least developed countries, one-third of death and disease is a direct result of environmental causes.
- In developed countries, healthier environments could significantly reduce the incidence of cancers, cardiovascular diseases, asthma, lower respiratory infections, musculoskeletal diseases, road traffic injuries, poisonings, and drownings.
- Environmental factors influence 85 out of the 102 categories of diseases and injuries listed in the *World Health Report*.
- Much of this death, illness and disability could be prevented through well-targeted interventions such as promoting safe household water storage, better hygiene measures, and the use of cleaner and safer fuels.
- Other interventions that can make environments healthier include increasing the safety of buildings, promoting safe, careful use and management of toxic substances at home and in the workplace, and better water resource management.

Sources: World Health Organization. *Protecting health from climate change: connecting science, policy and people*. Geneva: WHO; 2009. Available at: http://whqlibdoc.who.int/publications/2009/9789241598880_eng.pdf [Accessed 2 August 2012].

World Health Organization. *Ten facts on preventing disease through healthy environments*. Geneva: WHO. Available at: http://www.who.int/features/factfiles/environmental_health/en/index.html [Accessed 11 August 2012].
Bridge JW, Oliver DM, Chadwick D, Charles H, Godfray J, Heathwaite AL, et al. *Engaging with the water sector for public health benefits: water-borne pathogens and diseases in developed countries*. *Bull World Health Organ* 2010;88:873–5. Available at: <http://www.who.int/bulletin/volumes/88/11/09-072512.pdf> [Accessed 18 August 2012].

of sanitation, low housing standards, poor education (especially of girls), and high rates of poverty. These topics are addressed in the MDGs. Most of the diseases with large numbers of deaths are amenable to change with available

policies, technologies, and preventive and public health measures; these could result in 2.6 million fewer deaths annually from cardiovascular diseases, 1.7 million fewer deaths from diarrhea, 1.5 million fewer from respiratory diseases, 1.4 million fewer from cancers, and close to 1 million fewer from external injuries (motor vehicle accidents, poisonings, and others).

Sulfur and nitrogenous oxides from fossil fuel electric power plants can travel long distances after being released from tall chimneys. Pollutants falling as acid precipitation have led to the destruction of forests in countries of Central and Eastern Europe. Acid rain generated in one European country may fall in another, affecting bodies of water, animal life, and forests. Acid rain was reduced during the 1980s in North America by greater selectivity in fossil fuels, and the result is reduced damage to forests and water sources.

The release of various organic solvents, called chlorofluorocarbons (also known as freons or CFCs), used in cooling systems, refrigerators, and consumer aerosol products, causes damage to the Earth's ozone layer. This permits entry of ultraviolet (UV) light that was formerly excluded, into the Earth's atmosphere. UV light causes a rise in skin cancer and cataracts in humans. Substitution for freons is vital to reduce damage to the ozone layer, and can be achieved on an individual level by use of water-based paints and chemical products in daily life. The search for substitutes for refrigerants and toxic chemicals to replace those that damage the environment and exposed workers has, along with regulation, become the hallmark of environmental and occupational health.

Greenhouse gases are built up in the atmosphere by carbon dioxide emissions, largely due to increasing carbon dioxide and other gases produced from excessive and inefficient use of fossil fuels along with wide-scale destruction of forests, which are protective through natural conversion of carbon dioxide to water. These gases block infrared radiation from the Earth's surface, leading to trapping of heat. This effect resembles the use of glass or plastic covers to retain heat in a greenhouse. This global warming effect may have long-term serious consequences for the Earth's thermal balance. The effects on the polar ice caps can lead to global changes in the level of oceans. Reduction of the greenhouse effect requires international, national, and individual effort, and especially environmental consciousness and action by governments, the media, the scientific and business communities, as well as the general public.

Hazardous wastes are being exported from developed to developing countries. **Box 9.7** discusses e-waste, a phenomenon in which unwanted, old electronic equipment ends up and accumulates in various African countries. This situation is potentially solvable by heightened national awareness and stronger international conventions, with publicity and fines imposed by international courts against offending firms or nations. In a global economy, all of these factors

link up with effects on the physical environment as well as on working conditions and many social and political factors, such as the widening gap between rich and poor.

COMMUNITY WATER SUPPLIES

Freshwater is vital for all living organisms and is becoming an increasingly scarce resource. Waterborne diseases are among the major causes of death in developing countries, which often lack adequate supplies of water. In both developed and developing countries, pollution control, reuse of wastewater, and water planning are vital to the national economy and public health.

The International Decade for Drinking Water and Sanitation in the 1970s and early 1980s promoted national, binational, and international efforts to improve community water supplies, sanitation, drainage, education, and hygiene. Implementation of appropriate technology for maintaining water and sanitation infrastructure was emphasized. Safety of community drinking water, as defined by the WHO, requires a combination of standards and protection of raw water sources from contamination. Treatment of community water supplies requires sedimentation, coagulation, filtration, chlorination, and continuous monitoring. High standards of construction and maintenance of water distribution systems are needed, whether at the village well or in the municipal water supply system. Filtration removes solid and suspended particles, improving the quality of surface source water, and disinfection by chlorination effectively kills most microorganisms.

Covering and protection of reservoirs and canals is also beneficial in improving the security of water sources and in preventing contamination from natural sources, including birds, animals, and vegetation. Community water regulation and enforcement require both physical treatment and disinfection to protect the public against microbiological, chemical, and other health hazards. Agricultural runoff of pesticides and animal wastes are also important contaminants of water sources.

The Federal Water Pollution Control Act of 1948 was the first major US law to address water pollution. The Clean Water Act (CWA) of 1977 amended the 1972 Federal Water Pollution Control Act to address severe pollution of the Great Lakes and many of the major rivers of the USA. The CWA set new US national standards and regulatory mechanisms at federal, state, and local levels of government. It increased regulatory powers to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters". It included provisions for cooperation with Canada in cleaning up the Great Lakes.

The CWA gave the EPA the authority to implement pollution control programs such as setting wastewater standards for industry and water quality standards for all contaminants in surface waters. It made it unlawful for to

BOX 9.7 E-Waste

Africa is beginning to benefit from electronic modernization, such as cellular phones where no telephone landlines exist, and further electronic gains as development advances. In another respect, however, it has fallen victim to the information and technology revolution. As a continent, it currently serves as a disposal ground for unwanted, discarded, and outdated electrical equipment, which typically possess toxic properties and release hazardous chemicals into the environment. This major global issue is referred to as e-waste, “a generic term encompassing various forms of electrical and electronic equipment that are old, end-of-life electronic appliances and have ceased to be of any value to their owner”.

Examples of e-waste include televisions, cell phones, air conditioners, and refrigerators, which are transported from the developed world. The list of devices has greatly expanded through the years. The result is harmful pollutants into the atmosphere and underground water. E-waste disposal methods generally used (burning or landfill) contribute to the release of a mixture of toxic chemicals, harming the environment and humans, with leaching of poisons into groundwater aquifers following disposal.

Electronic devices contain a myriad of toxic compounds, and of particular concern is lead, characteristically found in high concentrations in many electronic products. Moreover, certain components such as polybutleneterephthalates (PBTs)

can accumulate to harmful amounts in living organisms. This may result even when limited quantities are dispersed, and consequently, PBTs place humans at risk for nerve damage, cancer, and reproductive complications.

Massive amounts of e-waste pose major problems in developing countries, which typically lack any form of infrastructure, defined protocols, or legislation to safely dispose of the e-waste and to cope with the overflow. Countries in West Africa, particularly Ghana and Nigeria, are especially burdened by electronic equipment waste. E-waste products are quite diverse and vary in complexity owing to the rapid evolution of new product design.

The lack of waste management protocols and enforcement in low-income countries allows this practice to continue. In contrast, regulations surrounding the disposal of unwanted devices are well established and growing in developed countries. The US Environmental Protection Agency informs consumers on ways to recycle or donate used electric devices, and many states have created specific laws pertaining to the disposal and recycling of electronic equipment.

Sources: Orisakwe OE, Frazzoli C. *Electronic revolution and electronic wasteland: the West/waste Africa experience.* *J Nat Envi Sci* 2010;1:43–7. Available at: <http://www.asciencejournal.net/asj/index.php/NES/article/viewFile/27/ORISAKWE> [Accessed 17 August 2012].
Environmental Protection Agency. *E-cycling* [updated 24 July 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/epawaste/conserve/materials/recycling/index.htm> [Accessed 15 August 2012].

discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. It provided grants for construction of sewage treatment plants. It also recognized the need for planning to address problems of non-point source, i.e., generalized pollution (EPA, *Laws and Regulations: History of the Clean Water Act*; 2013).

CWA regulations permitted effective action against industrial and other polluters and for controls to be established where multiple municipalities were involved in a river or regional water system. This has led to steady improvement in water quality of lakes, rivers, and groundwater sources throughout the country. However, a 2013 EPA report of a survey in 2008–2009 showed that: “21 percent of the nation’s river and stream length is in good biological condition, 23 percent is in fair condition, and 55 percent is in poor condition according to commonly used measurements” (EPA, 2013). A Clean Water Restoration Act proposed in the US Congress in 2007 is intended to clarify federal jurisdiction and standards of water supervision. However, it is controversial because of alleged federal infringement of state responsibilities (Box 9.8).

Concern about the potential carcinogenic effects of trihalomethanes may cause withdrawal of mandatory chlorination of surface waters. The absence of adequate disinfection with chlorine increases the risk of serious waterborne disease outbreaks such as the wave of cholera epidemics in South America during the 1990s. New standards may

require time to be implemented because of prevailing conservative professional and public attitudes and the cost of treatment plants. In Israel, for example, opinion gradually shifted towards a mandatory chlorination policy. This was due to a number of factors: increased public and news media awareness of drinking water quality, a greater recognition at the leadership level of the Ministry of Health of the importance of preventive and environmental factors in enteric disease, an increasing presence of younger, better trained sanitary engineers willing to challenge previously accepted dogmas, and persuasive documentation of the impact of contaminated community water supplies on the infectious disease burden of the country. Principles of water quality regulation are shown in Box 9.9.

Waterborne Diseases

Despite the long-standing success in reducing mortality and morbidity in the industrialized countries by emphasis on safe water supplies and careful monitoring, waterborne disease remains a serious challenge to public health in the twenty-first century. Waterborne diseases are among the most common causes of death in developing countries and remain an important public health issue even in high-income countries. They may be so common as to escape detection in point outbreak form. This seems to be the case in many countries, where hepatitis (especially hepatitis A

BOX 9.8 Clean Water Restoration Act

The Clean Water Act in 1972 made great progress in reducing pollution of waters and establishing standards for water quality in the USA and was a successful environmental law, but has fallen behind in recent years. The Act prohibits designated point source discharges, an oil spill prevention program, and the impaired waters cleanup program. The federal Environmental Protection Agency and Army Corps of Engineers regulations implement the law to protect all of America's waters, including tributaries, wetlands, and intrastate waters with linkages to interstate commerce. These rules were upheld by the vast majority of courts. In 1993, a large epidemic of waterborne cryptosporidium, a parasitic disease spread by contaminated water, occurred in Milwaukee with 400,000 cases and more than 100 deaths, which led to national concern regarding water safety in the USA.

The EPA regulates cryptosporidium in drinking water, and the regulatory process was strengthened by the Safe Drinking Water Act Amendments of 1996 providing funds to upgrade water treatment plants and requiring public drinking water suppliers to inform customers about chemicals and microbes in the water. The Great Lakes, the largest surface freshwater system in the world, provide drinking water to over 30 million people, some 10 percent of the US population and 30 percent of Canada's (EPA 2012). The International Joint Commission advises the national governments on issues regarding joint stewardship of the Lakes. The Great Lakes Cleanup of 1997 agreement between the US Environmental Protection Agency (EPA) and the Government of Canada agreed to a joint project to remove toxic substances from the Great Lakes by 2006.

In 2001, the Supreme Court ruled that non-navigable, intrastate waters are not protected by the Clean Water Act, weakening the regulation of national water systems. The Clean

Water Restoration Act of 2009, introduced by US Senator Russell Feingold, D-WI, would accomplish these important goals and has been endorsed by Clean Water Action. An EPA Hudson River Cleanup project in 2002 moved to clean up a 40 mile (64 km) stretch of the Hudson River of polychlorinated biphenyl (PCB) contamination, removing approximately 2.65 million cubic yards (3.5 million cubic meters) of contaminated sediment. The Clean Water Restoration Act of 2009 and 2010 clarifies the jurisdiction of the federal government over US waters.

In 2012, the 1624 miles (2614 km) of California coastline, from Mexico to Oregon, and surrounding major islands were deemed a no-discharge zone by the EPA as a ban was placed on large cruise ships and other large ocean-going ships from discharging any sewage into California's marine waters. Over 20 million gallons (75 million liters) of vessel sewage is kept off the state's beaches, a boon to the state's economy, helping to protect marine species, fisheries, residents, and tourists.

Sources: Clean Water Action. Overview: Clean Water Restoration Act of 2009. Available at: <http://www.cleanwateraction.org/mediakit/overview-clean-water-restoration-act-2009> and <http://www.govtrack.us/congress/bills/111/s787/text> [Accessed 27 June 2013].

US Environmental Protection Agency. Water: Clean Water Act 40th anniversary. Protecting and restoring our nation's waters. Available at: <http://water.epa.gov/action/cleanwater40/cwa101.cfm> [Accessed 27 June 2013].

US Environmental Protection Agency. Great Lakes. Basic Information, geography & hydrology. Available at: <http://www.epa.gov/greatlakes/basicinfo.html> [Accessed 16 July 2013].

US Congress. S. 787 (111th): Clean Water Restoration Act. Text as of 10 December 2010. Available at: <http://www.govtrack.us/congress/bills/111/s787/text> [Accessed 28 June 2013].

US Environmental Protection Agency. Water is worth it. Available at: <http://water.epa.gov/action/cleanwater40/> [Accessed 27 June 2013].

US Environmental Protection Agency. Laws and regulations. Available at: <http://www2.epa.gov/laws-regulations> [Accessed 27 June 2013].

and E) is endemic and where the incidence of gastroenteritis from *Shigella*, *Escherichia coli*, and rotavirus remains high. In industrialized countries, waterborne disease outbreaks have become uncommon events because of high levels of water management (Box 9.10).

Water contamination and enteric disease can also occur from organisms for which routine testing is not currently practiced. For example, testing for rotaviruses (which cause enteric disease) and organisms such as *Campylobacter* and *Giardia* is not done routinely; however, water is tested for these if there is a suspicion of contamination. Widespread infection of up to half of the world's population via contaminated water may have caused asymptomatic or symptomatic infection with *Helicobacter pylori*, the major cause of chronic peptic ulcer disease and gastric cancer (see Chapter 5). Safe water requires physical treatment as well as disinfection of all community water sources to ensure its safety during distribution to homes for private use. Effective water management can reduce the burden of gastroenteric disease even in a relatively

developed country (Box 9.11). The WHO water guidelines, which also incorporate chemical and radiation hazards, are periodically updated.

Israel, developing rapidly in the 1960s, built a national water carrier to distribute unfiltered, chlorinated water to communities and for agriculture. Local groundwater was not necessarily chlorinated, and sewage system development was inadequate. In the 1970s and 1980s, Israel experienced large numbers of waterborne disease outbreaks. A 1985 outbreak resulted from the contamination of groundwater sources by a sewage pipe which accidentally broke during roadwork, resulting in 9000 cases of shigellosis, 49 cases of typhoid fever, and one death. The introduction of mandatory chlorination in 1988 in Israel resulted in a substantial improvement in the quality of community water supplies and greatly reduced the incidence of waterborne disease outbreaks and the total burden of diarrheal disease (Tulchinsky et al., 2001).

An Environmental Protection Ministry is responsible for ensuring that all industries comply with the standards.

BOX 9.9 Principles of Water Quality Regulations

- There is an explicit link between drinking water quality regulations and protection of public health.
- Regulations are designed to ensure safe drinking water from source to consumer, using multiple barriers.
- Regulations are based on good practices proven to be appropriate and effective over time.
- A variety of tools are in place to build and ensure compliance with regulations, including education and training programs, incentives to encourage good practices and penalties, if enforcement is required.
- Regulations are appropriate and realistic within national, subnational and local contexts, including specific provisions or approaches for certain contexts or types of supplies, such as small community water supplies.
- Stakeholder roles and responsibilities, including how they should work together, are clearly defined.
- “What, when and how” information is shared between stakeholders – including consumers – and required action is clearly defined for normal operations and in response to incidents or emergencies.
- Regulations are adaptable to reflect changes in contexts, understanding and technological innovation and are periodically reviewed and updated.
- Regulations are supported by appropriate policies and programs.
- The aim of drinking water quality regulations should be to ensure that the consumer has access to sustainable, sufficient, and safe drinking water.
- Enabling legislation should provide broad powers and scope to related regulations and include public health protection objectives, such as the prevention of waterborne disease and the provision of an adequate supply of drinking water.

Sources: World Health Organization. *A conceptual framework for implementing the guidelines*. In: *Guidelines for drinking-water quality*. 4th ed. Geneva: WHO; 2011. Available at: http://www.who.int/water_sanitation_health/publications/2011/9789241548151_ch02.pdf [Accessed 15 August 2012].

Bridge JW, Oliver DM, Chadwick D, Charles H, Godfray J, Heathwaite AL, et al. *Engaging with the water sector for public health benefits: waterborne pathogens and diseases in developed countries*. *Bull World Health Organ* 2010;88:873–5. Available at: <http://www.who.int/bulletin/volumes/88/11/09-072512.pdf> [Accessed 18 August 2012].

Recycling of water for agricultural use has become a widespread practice, although recycled waste is not be used for household purposes. The shortage of water supplies has led to large-scale desalination along with improved water-pipe maintenance and conservation methods including reservoir construction.

There has been a marked reduction in the overall burden of enteric diseases in Israel, including hepatitis A; however, foodborne salmonellosis continues to be a public health problem. Initiatives to deal with overall water shortages include reclaiming sewage water for irrigation, drip irrigation, reducing water demand by one-third, desalination of

BOX 9.10 Control of Waterborne Disease as a Crucial Element in Reducing Morbidity and Mortality from Infectious Diseases, Twentieth Century, USA

“The 19th century shift in population from country to city that accompanied industrialization and immigration led to overcrowding in poor housing served by inadequate or nonexistent public water supplies and waste-disposal systems. These conditions resulted in repeated outbreaks of cholera, dysentery, TB, typhoid fever, influenza, yellow fever, and malaria.

By 1900, however, the incidence of many of these diseases had begun to decline because of public health improvements, implementation of which continued into the twentieth century. Local, state, and federal efforts to improve sanitation and hygiene reinforced the concept of collective ‘public health’ action (e.g., to prevent infection by providing clean drinking water).

By 1900, 40 of the 45 states had established health departments. The first county health departments were established in 1908. From the 1930s through the 1950s, state and local health departments made substantial progress in disease prevention activities, including sewage disposal, water treatment, food safety, organized solid waste disposal, and public education about hygienic practices (e.g., food handling and hand washing).

Chlorination and other treatments of drinking water began in the early 1900s and became widespread public health practices, further decreasing the incidence of waterborne diseases.” (CDC, 1999)

Sources: Centers for Disease Control and Prevention. *Achievements in public health, 1900–1999: control of infectious diseases*. *MMWR Morb Mortal Wkly Rep* 1999;48:621–9. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4829a1.htm> [Accessed 16 August 2012].
Centers for Disease Control and Prevention. *Achievements in public health, 1900–1999: changes in the public health system*. *MMWR Morb Mortal Wkly Rep* 1999;48:1141–7. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4850a1.htm> [Accessed 27 June 2013].

seawater, and building reservoirs to store rainwater. These measures have improved the water situation in the country, and thus a large industry of water systems technology has developed for international needs.

Waterborne Disease Surveillance and Prevalence, USA

During the nineteenth and early twentieth centuries, cholera and typhoid were major causes of waterborne disease outbreaks. Data collection on waterborne disease outbreaks in the USA dates back to 1920. Decades later, in 1971, the CDC, EPA, and Council of State and Territorial Epidemiologists collaborated to establish the Waterborne Disease and Outbreak Surveillance System (WBD OSS). This system allows experts to identify the prevalence and sources of outbreaks from water exposures which, in turn, helps to determine the epidemiology and the etiology of waterborne diseases. In many cases, the investigations reveal outbreaks resulting from pathogens or engineering problems within water systems. WBD OSS-documented outbreaks include those resulting from drinking water, recreational water, and

BOX 9.11 International, National, State, and Local Water Management Standards

- *International* – The United Nations and World Health Organization promoted the International Decade for Drinking Water and Sanitation and promulgated clear standards of water quality for community water supplies (1958, 1963, 1971, 1984, and 1997).
- *National, state, and local authorities* – policy commitment, funding, and professional departments for supervision of community water systems.
- *Municipal water systems* – water management and testing vary according to the quality of the source water and methods of treatment, including:
 - high standards of acceptability of source surface water
 - physical treatment: coagulation and filtration
 - disinfection by chlorination: routine and mandatory
 - maintaining and monitoring of residual chlorine
 - construction and maintenance of water storage and distribution systems
 - monitoring of enteric disease
 - investigation of suspected waterborne disease outbreaks
 - continuous monitoring by bacteriological and chemical testing
 - assurance of safe distance between sewage and water pipes
 - integrity of water distribution systems against inflow.
- *Village wells*
 - protection of wells from human and animal wastes
 - regular or periodic chlorination
 - supervision by trained and supervised village health workers.
- *Sanitary education* – at all levels of society including governments, non-governmental organizations, intersectoral cooperation, public, medical and other professional communities, and schools.

Source: World Health Organization. *Guidelines for drinking-water quality*. 4th ed. Geneva: WHO; 2011. Available at: http://whqlibdoc.who.int/publications/2011/9789241548151_eng.pdf [Accessed 15 August 2012].

other forms of water exposure. Samples from the patient and samples of water are examined and recorded, as are environmental components and water disinfection procedures. Surveillance is passive and reporting voluntary, so the figures obtained are not the complete incidence of waterborne outbreaks, as reporting depends on public awareness and resources accessible to local health departments.

Pathogens that have yet to be identified may play a crucial role in the future, owing to the changing characteristics of waterborne pathogens. Waterborne pathogens that require more of scientists' efforts include those that may be resistant to modern water treatment procedures. Recently, treatment protocols have been enhanced and upgraded in an effort to kill *Giardia* and *Cryptosporidium*, since outbreaks of these organisms in the USA have raised concerns,

as they are not efficiently eliminated by standard water treatment and are not routinely tested for in regular water-sampling monitoring. In addition, these waterborne organisms, among others, constitute a special risk for immunocompromised people, including cancer patients treated with chemotherapy, human immunodeficiency virus (HIV)-positive people, and patients on immunosuppressants following organ transplantation.

During 1991 to 2002 there were 2007 waterborne disease outbreaks reported in the USA, with 433,947 cases of illness reported. Problems in the distribution system were the most commonly identified deficiencies under the jurisdiction of a water utility, underscoring the importance of preventing contamination after water treatment. Most notably, in 1993, the largest reported waterborne disease outbreak in US history occurred in Milwaukee, Wisconsin, resulting in approximately 403,000 ill people, with 4400 requiring hospitalization. The organism responsible for the thousands of illnesses was *Cryptosporidium parvum*, a protozoan parasite that causes gastrointestinal problems. Transmission occurs by ingesting oocytes that have been eliminated from the body via animal or human feces. This has sparked increased focus on water quality assurance and epidemiological follow-up of waterborne disease.

Cryptosporidium can be transmitted from person to person, from animal to person, and by ingesting contaminated food or water. It can also be transmitted in swimming pools, and accordingly, this parasite is reportedly present in 65–87 percent of surface water samples tested in the USA. The degree of illness from this outbreak ranged from mild to severe among residents of Milwaukee, and attack rates were as high as 50 percent in some parts of the city. Most affected individuals experienced diarrhea, dehydration, and fever. Some cases resulted in deaths, which generally occurred among the immunocompromised or the elderly. The underlying cause of this massive Milwaukee outbreak was inefficiency of the water filtration process, causing contamination of a public water source. This resulted in the insufficient elimination of *Cryptosporidium* oocytes in one of the two major municipal treatment plants.

In 2011 the CDC's *Morbidity and Mortality Weekly Report* (MMWR) highlighted waterborne disease outbreaks in the USA, reporting 36 outbreaks documented during 2007–2008 with over 4000 cases of illness and three deaths. The four major illness recorded included outbreaks of acute gastrointestinal illness, acute respiratory illness, hepatitis and skin irritation related to a chemical exposure. Almost 60 percent of the 36 outbreaks were bacterial in nature, with a significant portion attributed to *Legionella*. The remaining etiologies include viruses, parasites, and chemicals. The underlying reasons for water contamination include untreated groundwater, treatment deficiencies, and substandard distribution systems. This report indicates the need for improved strategies to target, remove, and control

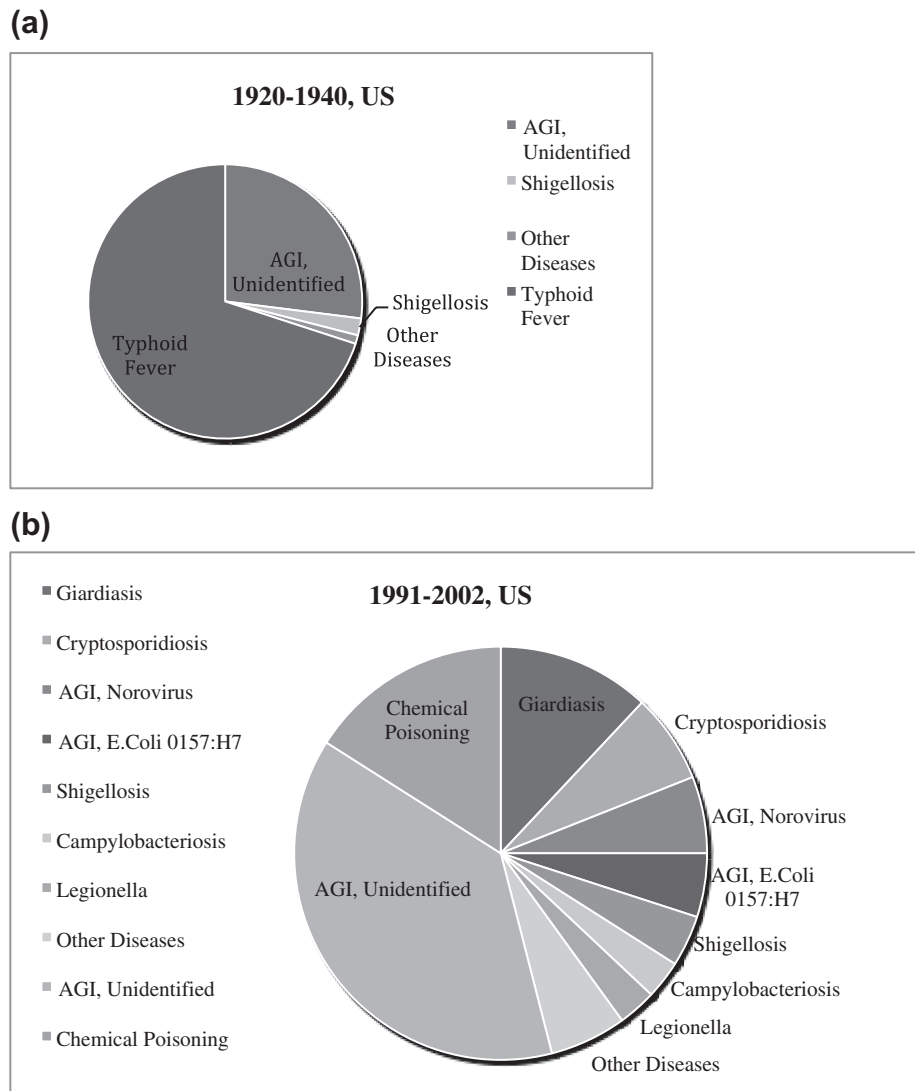


FIGURE 9.2 Etiology of waterborne diseases, USA, 1920–1940, 1991–2002. Note: AGI = Acute gastrointestinal illness. Sources: Adapted from Craun MF, Craun GF, Calderon RL, Beach MJ. Waterborne outbreaks reported in the United States. *J Water Health* 2006;2:19–30. Available at: <http://courses.washington.edu/h2owaste/group1.pdf> [Accessed 16 August 2012].

Lang IA, Galloway TS, Scarlett A, Henley WE, Depledge M, Wallace RB, et al. Association of urinary bisphenol A concentration with medical disorders and laboratory abnormalities in adults. *JAMA* 2008;300:1303–10. Available at: <http://jama.jamanetwork.com/article.aspx?articleid=182571> [Accessed 16 August 2012].

Melzer D, Rice NE, Lewis C, Henley WE, Galloway TS. Association of urinary bisphenol A concentration with heart disease evidence from NHANES 2003/06. *PLoS ONE* 2010;5:e867. Available at: <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0008673> [Accessed 16 August 2012].

Centers for Disease Control and Prevention. Surveillance for waterborne disease outbreaks associated with drinking water – United States, 2007–2008. *MMWR Surveill Summ* 2011;60(ss12):38–68. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6012a4.htm> [Accessed 19 August 2012].

Legionella, which is the most common documented etiology among outbreaks associated with drinking water in the USA.

The graphs in Figure 9.2 illustrate an interesting comparison and historical perspective, showing the major etiologies of US waterborne outbreaks from 1920–1940 and from 1991–2002. Looking at the first graph, it is evident that the recorded waterborne diseases each fall into one of four categories. When examining the graph representing

more the recent decades, we see the various diseases falling into several more classifications. Thus, the number of pathogens that have been identified as causative agents in waterborne disease outbreaks has expanded.

Early detection by laboratory diagnosis requires preparation of laboratories for identification of these organisms. Regular testing of the community water supply at its origin and within the supply system is essential to monitor water safety. The presence of coliform bacteria indicates fecal

contamination and potential hazards, warning sanitation officials that other more dangerous organisms, such as dysentery bacilli or enteric viruses such as hepatitis, may be present. Testing for *Cryptosporidium*, *Giardia*, and viruses is difficult, costly, and insensitive; therefore, routine testing is not done. Chlorination and filtration may not be sufficient to prevent waterborne disease transmission of these organisms. This is a problem for sanitary control, thus new methods of testing and disinfection of water supplies must be devised. At present, filtration and chlorination remain the basic methods of ensuring safe community water supplies, supplemented by boiling of suspect water during outbreaks of disease.

Standard water treatment processes (Figure 9.3) remove solid and suspended material, bacteria, and odors from water and have been outstandingly successful in reducing waterborne disease. New concerns over chemical contamination of community water supplies have become prominent in recent decades. Heavily polluted waters have been linked to neurological damage and cancers of the bladder, intestinal tract, liver, and kidney.

The US Safe Drinking Water Act of 1974, as amended in 1996, establishes criteria for monitoring of public water systems for microbiological, chemical, and other contaminants (Box 9.9). The act defines maximum contaminant

levels (MCLs) for specified chemical pollutants. The EPA sets MCLs for pollutants, out of hundreds of organic, inorganic, biological, and radiological contaminants detected in water supplies around the country. This area of public health concern still requires much epidemiological and sanitary engineering research.

Right-to-know laws, a critical investigative press, and an environmentally conscious public are fundamental to prevent serious ecological degradation. Environmental activism has made important contributions to public health, but such activism can be a two-edged sword. One example is the excessive zeal focused on the environmental impact of chlorination and its byproducts, in particular, trihalomethanes. This class of disinfectant byproducts is produced when natural organic and inorganic substances present in the water are combined with the disinfectants chlorine and chloramine. Total trihalomethanes include chloroform, bromoform, bromodichloromethane, and dibromochloromethane. The current MCL, which includes the combined concentrations of each of these four trihalomethanes, is 0.080 mg/l (EPA, 2012), although this level has changed throughout recent years. Similar to the case for other disinfectants, the MCL is set as a yearly average. People who drink water in which total trihalomethane levels exceed the

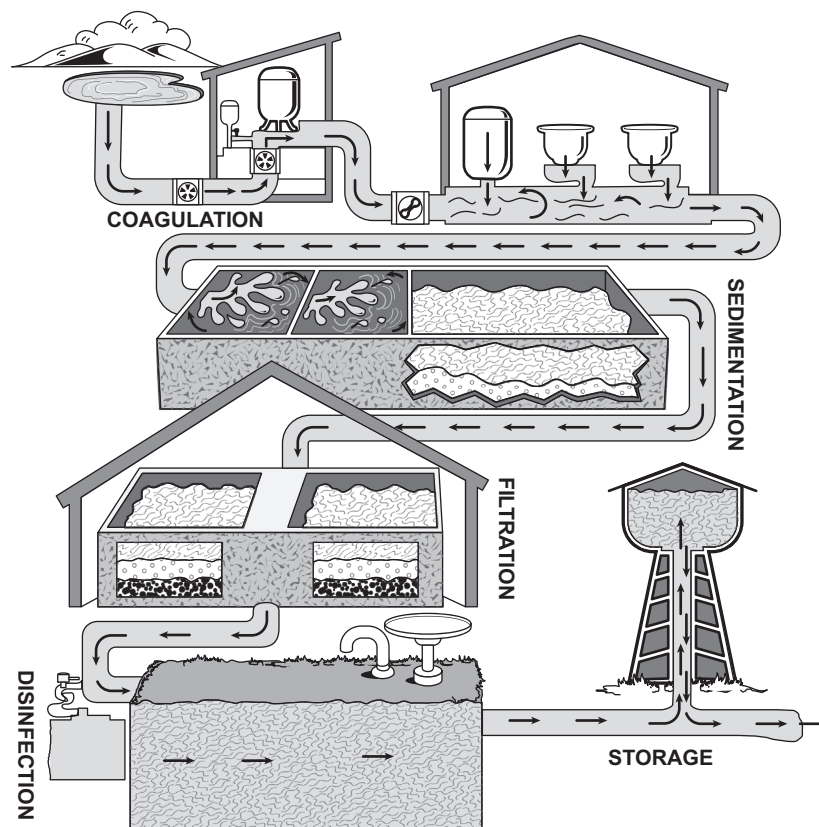


FIGURE 9.3 Process of community water treatment. Source: Centers for Disease Control and Prevention. Healthy water: community water treatment figure, courtesy of EPA [updated 3 April 2009]. Atlanta, GA: CDC. Available at: http://www.cdc.gov/healthywater/drinking/public/water_treatment_fig.html [Accessed 16 August 2012].

BOX 9.12 Water Contaminants Under US Environmental Protection Agency Regulation

- *Microorganisms* – turbidity, total coliforms, viruses, *Giardia lamblia*, *Cryptosporidium*, *Legionella*
- *Disinfectants* – chloramines and chlorine (as Cl₂), chlorine dioxide (as ClO₂)
- *Disinfection by-products* – bromate, chlorite, haloacetic acids, total trihalomethanes
- *Organic chemicals* – acrylamide, atrazine, tetrachloroethylene, carbon tetrachloride, vinyl chloride, benzenes, lindane, endrine, carbon tetrachloride, carbofuran, chlorobenzene, dichloromethane, dichloropropane, dinoseb, dioxin, diquat, endrin, epichlorohydrin, ethylbenzene, ethylenedibromide, glyphosate, heptachlor and epoxide, hexachlorobenzene, methoxychlor, oxamyl, polychlorinated biphenyls (PCBs), pentachlorophenol, simazine, styrene, tetrachloroethylene, toluene, toxaphene, trichloroethylene, vinyl chloride, xylene
- *Inorganic chemicals* – antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride (>4 mg/l), lead, mercury, nitrates, nitrites, selenium, thallium
- *Radionuclides* – alpha particles, beta particles and photon emitters, uranium, radium-226 and radium-228 (combined)

Note: Maximum contamination levels (MCLs) are set by the EPA for the listed contaminants.

Source: Environmental Protection Agency: *Water: drinking water contaminants* [updated 5 June 2012]. Washington, DC: EPA. Available at: www.epa.gov/safewater/contaminants/index.html#micro [Accessed 16 August 2012].

established MCL over a period of several years can develop liver, kidney, or central nervous system damage and may be at increased risk for cancer.

Opposition to disinfection by use of chlorination led to the spread of cholera in South America during the 1990s (see Chapter 4). The offset of benefits against risks has resulted in current professional consensus that this is not a justification to cease chlorination. Rather, it provides additional justification for physical treatment of raw water before chlorination to reduce the nitrogenous material content and thereby reduce the combination with chlorine which produces trihalomethanes, improving water potability and clarity. Residual chlorine within the water distribution system is a protector for cross-contamination from sewage sources where maintenance of pipes and valves may be inadequate in aging distribution systems.

Developmental programs including local and large-scale dam projects can have negative health effects by providing a hospitable environment for vectors for diseases such as malaria, schistosomiasis, and onchocerciasis, resulting in the resurgence of diseases once controlled. Planning of development projects must take into account the potential ecological effects and the needed control measures to

prevent greater health damage than benefit. Box 9.12 shows major waterborne disease contaminants that are defined by EPA regulations.

WATER AS A GLOBAL RESOURCE

Created in 2003, UN-Water is the United Nations interagency collaboration organization for all issues pertaining to freshwater. Its purpose is to assess and document the conditions and utilization of freshwater resources on a global scale. UN-Water's important functions include evaluating a geographic region's past and determining whether and how much progress has been made. Notable advances have been achieved through WASH (water, sanitation, and hygiene) services.

UNICEF reports that MDG target 7c, of reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation, was reached by 2010. This means that the percentage of individuals who have no access to improved drinking water sources was reduced by more than half since 1990. The figure dropped from 24 percent to 11 percent, as more than 2 billion individuals obtained access to improved water.

This is a significant achievement, but the benefits of clean water are not available equally or uniformly. Only minimal advancement has been made in expanding access to drinking water among those living in poverty in sub-Saharan Africa and in access to sanitation facilities among the poor in South Asia, especially in rural regions. The primary challenges impeding continued progress in making safe drinking water available to everyone are issues of disparities and insufficient human and financial resources.

In March 2011, the United Nations Development Programme (UNDP) stated that, "the right to water emphasizes the importance of water-related development for marginalized and vulnerable groups, who are commonly socially excluded" (UNDP, 2011). In a 2012 WHO document discussing environmental health inequalities in Europe, rural populations in particular are identified as a vulnerable group. In examining the prevalence of inadequate water supply among several European countries, data demonstrate that rural populations are significantly more affected by this than urban populations. Those residing in rural areas are especially exposed to sources of inadequate drinking water, and this puts them at increased risk for waterborne diseases. Underlying reasons for this disparity include distance to water sources, minimal access to a water distribution network, and cost, as the price associated with water services is substantially higher in rural regions than in urban areas. The availability of safe, potable water for vulnerable populations would lead to marked improvements in the health status of many, as the risk of diarrheal diseases would drop and better hygiene would be maintained. Moreover, access to improved water may result in less of a need for both storing water in the home and transporting water. This is an

BOX 9.13 Population Growth, Food Security, Water Scarcity, Science and Technology

The global population of some 7 billion people will increase by another 2 billion by 2050. The highest rates of population growth are occurring in water-scarce sub-Saharan Africa. Water security is essential for human life, socioeconomic development, and healthy ecosystems. Urban development requires increased utilization of groundwater and surface water sources for domestic, agricultural, and industrial needs. Population and economic growth requires more food production, which demands large amounts of water (e.g., 1 kg (2.2 lbs) of wheat consumes 1500 liters (US 396.3 gal) of water).

Water use has grown at more than twice the rate of population increase in the past century. Although there is enough freshwater on the planet for 6 billion people, it is distributed unevenly and much is wasted, polluted, and unsustainably managed. Thus, pressure on water resources intensifies, with conflicts among users and damage to the environment. For example, Ethiopia is building a dam on the upper Nile, which Egypt views as a threat to its water supply.

Water scarcity affects every continent. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of scarcity, with another 500 million people close to this situation. A further 1.6 billion people (one-quarter of the world's population) face water shortage due to lack of infrastructure to harvest, transport, and utilize water from surface and aquifer sources. Water scarcity limits agricultural production, leads to population relocation from regions impacted by droughts, and adversely affects food security in developing countries.

Recent evidence indicates that the notoriously dry continent of Africa has vast reservoirs of deep aquifers with 100 times the amount of surface water. But the challenges of secure recovery systems require good stable governance, massive investment, and improved distribution and utilization systems. Developed countries such as the USA also face serious national and regional water shortages.

Important innovations developed to meet the growing challenge of water scarcity include:

- safe water recovery from wells and surface water with protection from contamination
- safe water processing – filtration, chlorination, and new innovations in microfilters
- improved distribution systems

- monitoring and replacement of leaking distribution systems that waste large amounts of treated water
- improved irrigation techniques – drip irrigation, sprinklers, microsprinklers
- new plant varieties that can survive drought conditions
- home and industrial wastewater recovery and treatment – now over 75 percent utilized in Israel
- storage of runoff waters
- rainwater collection and storage
- desalination – now provides half of total water usage in some countries
- filtration and treatment technologies – self-cleaning filtration systems
- decontamination – from oil and chemical contamination
- community education to reduce overusage of scarce water – reduced garden irrigation, toilet flushing using “gray water” (e.g., from showers, kitchen sink).

Safe water in adequate quantities for a growing world population with potential for serious climate change will make water conservation and innovative management a crucial public issue in the coming decades.

Note: Maximum contamination levels (MCLs) are set by the EPA for the listed contaminants.

Sources: Environmental Protection Agency. *Water: drinking water contaminants* [updated 5 June 2012]. Washington, DC: EPA. Available at: www.epa.gov/safewater/contaminants/index.html#micro [Accessed 16 August 2012]. United Nations Department of Economic and Social Affairs. *International Decade for Action: Water for life, 2005–2015*. New York: UNDESA. Available at: <http://www.un.org/waterforlifedecade/scarcity.shtml> [Accessed 16 August 2012].

UN-Water. *Coping with water scarcity, a strategic issue and priority for system-wide action*. New York: United Nations; 2006. Available at: <ftp://ftp.fao.org/agl/aglw/docs/waterscarcity.pdf> [Accessed 18 August 2012].

Organisation for Economic Co-operation and Development. *Biodiversity, water and natural resource management: Global Forum on Environment: Making Water Reform Happen*. OECD Conference Centre, Paris 25–26 October 2011. Available at: <http://www.oecd.org/env/resources/globalforumonenvironmentmakingwaterreformhappen.htm> [Accessed 1 December 2013].

World Health Organization/United Nations Children's Fund. *Progress on drinking water and sanitation: 2012 update*. Geneva: WHO/UNICEF; 2012. Available at: <http://www.unicef.org/media/files/JMPPreport2012.pdf> [Accessed 16 August 2012].

Mekorot: Israel National Water Company. *Wastewater treatment and reclamation*. Tel Aviv: Mekorot. Available at: <http://www.mekorot.co.il/Eng/Activities/Pages/WastewaterTreatmentandReclamation.aspx> [Accessed 18 August 2012].

important and favorable outcome, as typically, it is these actions that play a role in water contamination.

The MDG to improve access to clean drinking water has made good progress since 2001. Globally, population coverage with safe water increased from 77 percent in 1990 to 87 percent in 2008. An estimated 1.1 billion people in urban areas and 723 million people in rural areas gained access to improved drinking water sources over the period 1990–2008. However, the most vulnerable populations still lack such access (UN, 2013; Millennium Development Goals Report 2013; UNICEF, 2012). Consequently, water scarcity is identified as a major global problem (Box 9.13).

SEWAGE COLLECTION AND TREATMENT

Sewage collection and treatment, along with filtration and disinfection of drinking water, have made enormous contributions to improved public health, perhaps even more than the use of modern medicines and vaccines. Collection of sewage prevents surface environmental contamination as well as seepage into groundwater and contamination of local water sources. Sewage contains bacteria, viruses, protozoa, and other pathogens that can cause serious disease; treatment entails killing the pathogenic organisms present in the sewage. The purpose of sewage treatment is to improve the

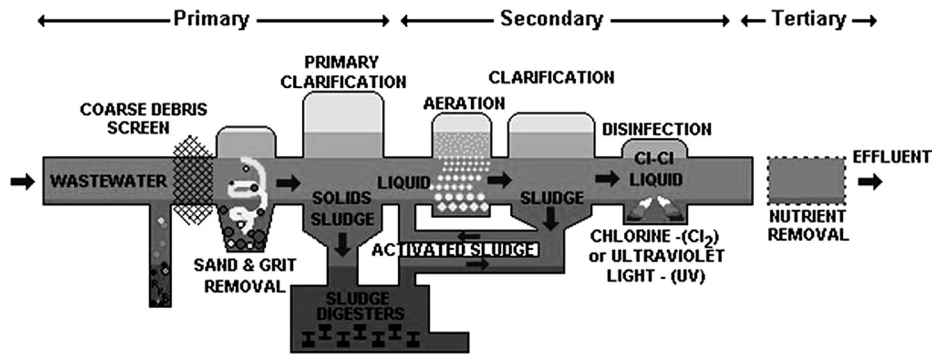


FIGURE 9.4 Wastewater treatment process. Source: *Water Treatment Process. Waste water treatment process.* Available at: <http://watertreatment-process.net/waste-water-treatment-process/waste-water-treatment-process/> [Accessed 16 August 2012].

quality of wastewater to a level where it can be discharged into a waterway or prepared for reuse for agriculture without damaging the aquatic environment or causing human health problems in the form of waterborne disease.

Figure 9.4 illustrates each level involved in the wastewater treatment process. Primary treatment of community wastewater begins with the removal of solids from the wastewater, through several mechanical processes of screening and sedimentation. The wastewater is passed through screens to remove large solid objects and then through grinders to further break up the solid wastes. The wastewater then flows at reduced velocity through a grit chamber where sand, gravel, and other inorganic materials settle out. Air is injected into the tank to remove trapped gases and to maintain an aerobic environment. The wastewater then flows into secondary settling tanks where further sedimentation of solid particles takes place. Primary treatment removes just over half of the suspended material and particles in preparation for secondary treatment.

Secondary treatment of wastewater is based on biological treatment assisted by mechanical methods, accelerating the natural decomposition of organic wastes. Aerobic microorganisms are used in the presence of an abundant oxygen supply to decompose the organic material into carbon dioxide, water, and minerals. The wastewater is sprayed over trickling filters or beds of crushed stone covered with a slime containing various types of microbes. These microbes absorb the organic material and act to break it down into its various components. The sewage is then processed by the activated sludge method, carried out by introducing bacteria-containing sludge into a tank of wastewater along with compressed air. The waste is then agitated and mixed for 4–10 hours. The microbes are adsorbed to suspended particles and oxidize the organic material. After this process, the sludge, consisting of masses of bacteria, settles out into the tank. The sludge is then removed and recycled into the next tank of wastewater.

Following primary and secondary treatment, the suspended material and the biochemical oxygen demand

(BOD) are reduced by approximately 90 percent. This process depends on temperature, which affects the metabolic rate and activity of the organisms needed to break down the suspended organic material. Secondary treatment is most effective in removing protozoa, worms, and bacteria, but less effective against viruses, heavy metals, and other chemicals. Since 1988, all sewage plants in the USA have been required by federal regulations to provide at least secondary treatment.

Tertiary treatment is required if the wastewater is to be recycled for the purposes of agricultural irrigation, recreation, or community use. Tertiary treatment includes a combination of physical, chemical, and biological processes to reduce the particles and BOD to less than 1 percent of those of the original wastewater. The process includes chemical coagulation, filtration, sedimentation, activated carbon adsorption, oxygenation ponds and aerated lagoons, osmosis, ion exchange, foam separation, and land application. All of these processes remove different pollutants present in the wastewater, especially tiny particles of suspended organic matter. They also remove synthetic chemicals, ammonia, nitrates, phosphates, and dissolved organic materials. Recycled wastewater is an important source of water in a world running short of water. Desalination is also becoming an attractive option as the costs of treatment are reduced and become competitive with other forms of water management. Another important potential in new technology is to use evaporated water in the air as a source of household water supply.

Disposal of the sludge remaining after sewage treatment by incineration or ocean dumping is environmentally problematic. Use of the sludge for compost in agriculture or gardening is increasing, but contamination may enter the food chain and create another hazard. Sludge disposal should be carefully regulated.

Reuse of treated sewage water has become important in national water management systems to address widespread shortages of high-quality water supplies from surface or groundwater sources.

Disinfection is the final stage, accomplished by introducing chlorine into the water so that there is a residual level of chlorine to protect the water from contamination in the water storage and distribution system. In many countries or regions, lack of sufficient local water supplies for community agriculture and industrial uses necessitates recycling of wastewater as part of the process of water conservation. Supplementation of water sources by desalination and recycling will be increasingly important as population growth, increasing standards of living, and pressures of agricultural and industrial contamination of water sources increase. New technology in membrane filtration offers hope to improve the efficiency and economics of this sector of the ecological sciences. The post MDG 2015 period will require renewed effort to improve sanitation with infrastructure development with new methods of water and sewage management to reach the poor people so far bypassed.

SOLID WASTE

The disposal of solid waste has been a challenge from prehistoric to modern times which will only increase in the future. With the growth of cities, the disposal of refuse took on a more significant health importance. In biblical times, Jerusalem burned its garbage in a valley outside the city walls (the valley of *Gehennam*, a term later adopted for “Hell”). The Greek city-states had ordinances against dumping refuse in or near cities, providing waste disposal sites for this purpose. In medieval European cities, garbage as well as human and animal wastes were discarded into the streets and areas surrounding the home. In the thirteenth century, Parisians were forbidden to throw waste on the streets and had to dump it outside the walls of the city. In 1388, the English parliament prohibited waste disposal in public waterways. During the industrial revolution, medieval cities evolved into working-class slums. Crowding, poor housing, and poor sanitation forced municipal governments to organize measures to reduce the nuisance and health hazards of solid waste.

Waste management continues to be a problem as greater amounts are generated by the affluent lifestyles of the population of industrialized countries. In developing countries, where rural to urban population shift is under way on a massive scale, rapid population growth, crowding, and slums increase the burden of solid waste disposal. Since the 1980s, return, recycling, and reuse of waste products have entered the popular culture in many countries, and these practices are beginning to have an impact on reducing landfill needs. Recycling of paper, plastic, glass bottles, and metals contributes to reduced solid waste for disposal and has become an economically attractive activity. Biogas methods are improving so that animal wastes can be used for production

of methane gas to be used for energy produced for home or general use.

Waste management is becoming more controversial. There is confusion about the differences between issues such as hospital waste, industrial waste, and toxic household waste, and a lack of trust by the community in governments and scientific communities. Hence, there is great need for continuing community education and communication by government agencies and community leaders.

In the USA, 95 percent of solid wastes comes from agriculture, mining, and industry. The remainder is from household waste, which generates 150–180 million tons (approximately 140–160t) of solid waste annually. This is the equivalent of 4 pounds (1.8kg) of refuse per person per day. Municipal waste collection and disposal are serious problems involving high costs and a serious public health burden if not done well.

Waste management involves a variety of techniques, including reusing and recycling, composting, incineration, and land refill. Each has its advantages and disadvantages. These techniques are part of the engineering of community infrastructure. Seawater dumping is still practiced in some countries, but increasing global concern about the effects of such practices on the ecology of the lakes and oceans makes this solution unacceptable. Landfill is the most prevalent method of solid waste disposal. It involves spreading garbage in layers 8–10 feet (2–3 m) deep and covering them with a thin layer of soil. This method is adequate if well planned and supervised and has the benefit that methane gas produced by anaerobic decomposition can be recovered for use. The problems of seepage of toxic materials and potentially explosive gas accumulation require careful assessment of landfill sites and limit the potential of landfills to serve as a sustainable, feasible option. Limited possibilities for suitable landfill locations in large urban concentrations make this method of disposal a serious urban planning problem. Sanitary landfill is expensive because of the cost of collection and transportation, the land value, and the human resources required. Landfill under sanitary conditions requires compaction of waste and covering by well-spread yet compacted earth far from ground and surface water. The site must be fenced to prevent scavenging by people, animals, and off-hours dumpers. The landfill should be located away from residential areas, be well maintained and tidy, and have well-paved and well-drained access roads. It should be seeded, in completed areas, with grass and trees to control erosion, and must be maintained by well-trained sanitarians.

Composting or conversion of waste products into topsoil can be applied at the household and municipal levels. Byproducts of wood and food processing can be composted and used to reduce soil pollution from petroleum-based products. This process involves separation of non-biodegradable from biodegradable materials and their treatment to break

TABLE 9.2 Hazardous Waste Disposal Sites: Summary of Epidemiological Evidence

Health Effect	Level of Evidence	Health Effect	Level of Evidence
Early fetal deaths (spontaneous abortion)	Inadequate	Orofacial birth defects	Inadequate
Late fetal deaths (stillbirths)	Inadequate	Musculoskeletal birth defects	Inadequate
Intrauterine growth retardation	Inadequate	Genitourinary birth defects	Limited
Small for gestational age	Inadequate	Gastrointestinal birth defects	Inadequate
Birth weight adjusted for gestation length	Inadequate	Chromosomal abnormalities (structural)	Inadequate
Term birth weight	Inadequate	All childhood cancers	Inadequate
Low birth weight (not adjusted for gestation length)	Limited	Leukemia	Inadequate
Preterm birth, gestation length	Inadequate	Lymphoma	Inadequate
Total birth defects	Limited	Reproductive system development	Inadequate
Central nervous system birth defects	Limited	Thyroid function	Inadequate
Cardiovascular birth defects	Limited	Kidney function	Inadequate

Sources: World Health Organization. Population health and waste management: scientific data and policy options. Report of a WHO Workshop, 2007, March 29–30, Rome, Italy. Copenhagen: WHO, European Region; 2007. Available at: http://www.euro.who.int/_data/assets/pdf_file/0012/91101/E91021.pdf [Accessed 17 August 2012]. Agency for Toxic Substances and Disease Registry [updated 14 August 2012]. Atlanta, GA: ATSDR. Available at: <http://www.atsdr.cdc.gov/> [Accessed 15 August 2012]. Environmental Protection Agency. Household hazardous wastes [updated 24 July 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/osw/conservematerials/hhw.htm> [Accessed 15 August 2012].

down organic waste. Decomposition at high temperatures (140°F, i.e., 60°C) kills flies, weed seeds, and potentially pathogenic organisms. In closed systems with forced draft aeration, this process can be accomplished in a few days; however, with passive methods it takes many months. After further treatment of “curing” and screening or grinding, an excellent soil conditioner can be produced that can be used to enhance agricultural or horticultural work such as in nurseries, public gardens, and parks. Incineration is attracting wide interest, but its use is limited by high capital cost and the possible release of potentially toxic materials such as dioxin and heavy metals into the atmosphere.

Meticulous maintenance is needed to thoroughly mix the materials for clean burning at high temperatures. In addition, there is the residual problem of disposal of the ash, which is toxic. Waste-to-energy incineration reduces the volume of waste products by 80–90 percent and produces energy that can generate electricity and replace fossil fuels. In Japan and Western Europe, 30–40 percent of solid waste is incinerated in waste-to-energy plants.

Using garbage as feed for pigs is no longer acceptable because of the problem of meat contamination with trichinosis (pork tapeworm). However, the practice is returning on an experimental basis with scraps ground and steamed before being used as animal feed. Control of the use of animal parts for animal feed is now being re-evaluated and more intensively regulated following the bovine spongiform encephalopathy (BSE) experience in the UK and Europe in the 1990s (see Chapter 4).

Recycling and waste reduction are methods gaining wide support. Reducing the use of disposables (e.g., packaging materials, disposable diapers) requires an ecologically conscious public, and municipal, non-governmental, or volunteer collection systems. Scrap metal, paper, glass, and plastic recycling can be commercially successful. Industry and commercial enterprises can be convinced to reduce the use of bulky packaging materials and to adopt “ecologically friendly” practices. Plastics and rubber tires are also recyclable in economically valuable ways. Ecological consciousness is fundamental to the success of such practices.

The potential harmful effects of hazardous waste sites are shown in Table 9.2. The location and management of landfills requires professional management with a fair and transparent process and involvement of the community, with a focus on replacing poor-quality landfill practices. Epidemiological surveillance programs should only be undertaken after a feasibility analysis and with suitable protocols. The chemical exposure pathways and the effects on at-risk segments of the population should be considered. The adverse effects on health from factors such as noise and odor, negative impacts on property values, and the views of the community should all be considered. A 2007 WHO review of the epidemiological evidence of hazardous waste effects on health showed such evidence to be weak or limited (Table 9.2).

Production of both steel and aluminum from virgin ore is very polluting and energy intensive. Therefore, recycling of iron, steel, and aluminum in the USA makes up a substantial part of total new production of these metals.

Use of recycled iron and steel reduces air pollution by 86 percent, water pollution by 76 percent, and solid wastes by 105 percent, compared to production from new ores. Similar benefits accrue from recycling of aluminum scrap. In North America, steel is the most recycled material. During the first 6 months of 2013, recycling of steel was 37.6 million tons compared to recycling of paper, 25.5 million tons; aluminum, 2.3 million tons; glass, 1.6

million tons; and plastics, 1.2 million tons. Community waste collection and recycling has become widely practiced in many countries. In the USA, the rate of recycling municipal waste products has doubled to over 32 percent of total waste, saving some 64 million tons of household waste from landfill or incinerator disposal. In 2011, recycling and composting of trash was about 250 million tons, equivalent to a rate of 34.7 percent of total waste in the USA (EPA 2011).

BOX 9.14 Hazardous Substances: Chemical Classifications According to their Structure, Properties, or Use

Chemical classes are groupings of those related by similar features: by their structure (e.g., hydrocarbons), uses (e.g., pesticides), physical properties [e.g., volatile organic compounds (VOCs)], radiological properties (e.g., radioactive materials), or other factors, as used by the US Agency for Toxic Substances and Disease Registry (ATSDR) to address hazardous substances.

Chemical Classification

- Benzidines/aromatic amines
- Dioxins, furans, polychlorinated biphenyls (PCBs) (contain phenyl rings of carbon atoms)
- Hydrocarbons (contain hydrogen and carbon atoms)
- Inorganic substances
- Metals/elements (the simplest forms of matter)
- Nitrosamines/ethers/alcohols
- Organophosphates and carbamates
- Pesticides (chemicals used for killing pests, such as rodents, insects, or plants)
- Phenols/phenoxy acids
- Phthalates
- Radionuclides (radioactive materials)
- Volatile organic compounds
- Warfare and terrorism agents (used in acts of war or terror)

Most Viewed Toxic Substances

- Aluminum
- Ammonia
- Arsenic
- Asbestos
- Benzene
- Cadmium
- Chromium
- DDT, DDE, and DDD
- Formaldehyde
- Lead
- Mercury
- PCBs
- Polycyclic aromatic hydrocarbons (PAHs)
- Toluene
- Trichloroethylene (TCE)

Source: Agency for Toxic Substances and Disease Registry [updated 14 August 2012]. Atlanta, GA: ATSDR. Available at: <http://www.atsdr.cdc.gov/> [Accessed 15 August 2012].

TOXINS

A toxin is a substance in the environment with the potential for causing human disease or injury. Toxicology is the study of such substances and their effects on humans. All chemicals are toxic under some conditions, depending on the dose, concentration, and threshold or sensitivity of a given species for that substance. The range of chemical toxins and methods of classifying them are shown in Box 9.14.

The factors that affect the toxicity of an agent, in addition to the extent and duration of exposure, include host factors (e.g., age, gender, fitness level, previous exposure), environmental factors (e.g., temperature, air flow), and the

BOX 9.15 Basic Concepts of Toxicology

- *Bioavailability* – the ability of a substance that enters the body to be liberated from its environmental matrix (water, tissue, soil) and to enter the circulation of the host.
- *Dose–response relationship* – the relationship between the quantity of a toxicant received by the host and the probability of an effective concentration at the vulnerable site.
- *Intermediary metabolism* – the metabolic changes that a chemical undergoes once it reaches the cells of the body, usually in the liver. The substance may be detoxified to benign compounds, or may be converted to biologically harmful metabolites. The toxic substance acts on a cellular or subcellular level to disrupt the living organism. Some toxic agents are metabolic poisons; others act on cell membranes, interfere with chemical reactions, or bind to nucleic acids.
- *Susceptibility* – the ability of a living thing to be harmed by an agent, which may be influenced by age, gender, genetic disposition, nutrition, prior exposure, immune state or general health, stress, location at work, airflow, temperature, and humidity.
- *Threshold* – the lowest dose of a chemical that has a detectable effect.
- *Toxic effect* – damage to an organism as measured in terms of loss, reduction, or change of function, clinical symptoms, or signs. Effects may be adverse in one person and not in others.

nature of the toxic agent (e.g., physical and chemical properties) (Box 9.15). Toxicology is an important part of environmental and occupational health; further reference will require a specialized text and appropriate Internet websites (see Bibliography).

Toxic Effects on Fertility

Toxins can adversely affect fertility, pregnancy, and early or later child development. Reproductive potential can be adversely affected by reduced male reproductivity, such as by exposure to the pesticide dibromochloropropane (DBCP). Other chemicals have been implicated in increased abortion rates among exposed pregnant women; for example, birth defects or teratogenesis occurred with exposure to thalidomide. Other chemicals relate

to low birth weight and toxicity in newborns. Exposures to chemicals such as lead produce brain damage in children.

Teratogens are substances that cause birth defects, diseases, or abnormalities in the embryo or fetus either by disturbing maternal homeostasis or by acting directly on the fetus. Birth defects historically were attributed to retribution for sin, witchcraft, or moral or physical defects in the mother. Scientific knowledge of genetic disorders has grown since the 1940s, and many agents have been shown to cause birth defects. Such agents act on fetal development and not on genetic DNA, so that a threshold effect is assumed; that is, the effect occurs only if the causative exposure is above a certain threshold. Some currently known teratogenic agents and their effects are shown in Table 9.3.

TABLE 9.3 Teratogens and Their Effects on the Fetus and Newborn

Teratogen	Effects on Fetus and Newborn
Maternal Infections	
Rubella	Congenital rubella syndrome, deafness, cataracts, heart defects
Syphilis, herpes simplex	Mental retardation, microcephaly
Cytomegalovirus	Infected kidney, liver, lungs
Toxoplasmosis	Central nervous system lesions
HIV	HIV neonatal transmission
Others – varicella, mumps, parvovirus	Nerve deafness
Nutritional deficiency	
Protein deficiency	Abortion, prematurity, low birth weight
Folic acid deficiency	Anencephaly, spina bifida
Ionizing radiation	
X-rays or nuclear radiation or fallout	Central nervous system disorders, microcephaly, mental retardation
Drugs	
Alcohol	Mental retardation, microcephaly, facial defects
Cocaine	Prematurity, retardation, addiction
Thalidomide	Phocomelia (i.e., small deformed limbs)
Dilantin, valproic acid	Heart malformations, cleft palate, retardation, microcephaly
DES (diethylstilbestrol)	Vaginal cancer in girls, genital deformities in boys
Anesthesia	Miscarriages, structural deformities
Barbiturates	Heart defects, microcephaly, retardation
Chemicals and heavy metals	
Methyl mercury, lead, cadmium	Miscarriages, mental retardation, neurological disorders
Dioxin	Physical deformities, miscarriage
Cigarette smoke – direct and “secondhand smoke”	Miscarriage, prematurity, low birth weight

Sources: Nadakavukaren A. Our global environment: a health perspective. 7th ed. Prospect Heights, IL: Waveland Press; 2011.

Chung W. Notes: teratogens and their effects. New York: Columbia University. Available at: <http://www.columbia.edu/itc/hs/medical/humandev/2004/Chpt23-Teratogens.pdf> [Accessed 18 August 2012].

University of New South Wales. Abnormal development teratogens [updated 5 November 2011]. Sydney: UNSW, Embryology. Available at: http://php.med.unsw.edu.au/embryology/index.php?title=Abnormal_Development_-_Teratogens [Accessed 18 August 2012].

Toxic Effects of Lead in the Environment

In the USA in the 1920s, the use of tetraethyl lead in fuel was promoted to improve automobile performance. This led to a long struggle between public health regulatory agencies and the automobile industry. Industry won, and leaded gasoline was used well into the 1960s and is still available in many parts of the world. Alice Hamilton investigated the widespread use of lead in industry during the 1920s and successfully lobbied for legislative changes to increase surveillance and improve safety by reduced exposure (Box 9.16). Community exposure to lead was identified as a public health problem in the 1960s when trace quantities were found in food, beverages, soil, and air. The main sources of community exposure were from leaded fuels for cars and lead-based paints manufactured from the 1920s to the 1960s.

Children are especially vulnerable to these environmental contaminants. Clinical effects appeared particularly in children and at lower blood concentration levels than previously thought to be significant. "Acceptable" levels were lowered and lead abatement programs introduced. These programs were especially needed in urban slum areas, where children were exposed to lead-based paints in older homes and heavy urban traffic. Consequently, many children were found to have high blood lead levels (BLLs), placing them at risk of brain damage.

Since 1991, the recommended standard of lead exposure necessitating follow-up action was 10 µg/dl in blood samples. Between 1991 and 1994 in the USA, 4.4 percent of children

BOX 9.16 Alice Hamilton and Tetraethyl Lead

Alice Hamilton, a pioneering researcher and public health advocate in the 1910s and 1920s, demonstrated workplace hazards and toxic substances such as white phosphorus used in match production, lead additives to gasoline, and radium in watch dials. Tetraethyl lead (TEL) was produced and promoted by DuPont, despite being identified as hazardous.

Despite strenuous opposition from Hamilton and others, the use of TEL use expanded, and with it her research on behalf of state and federal government commissions. Environmental lead toxicity increased until the 1970s, when further research revealed the extent of the problem and its public health effects, especially on children. Hamilton's work set standards for toxicology research in occupational and environmental health that led to the regulatory successes of the 1970s in the USA.

Sources: Rossner D, Markowitz GA. "Gift of God"? The public health controversy over leaded gasoline in the 1920s. *Am J Public Health* 1985;75:344–52. Available at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1646253/> [Accessed 17 August 2012].

Centers for Disease Control and Prevention. *Achievements in public health, 1900–1999: Improvements in workplace safety – United States, 1900–1999*. *MMWR Morb Mortal Wkly Rep* 1999;48:461–9. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4822a1.htm> [Accessed 17 August 2012].

1–5 years of age had elevated BLLs (> 10 µg/dl). In 1992, the American Academy of Pediatrics adopted a lower BLL as a danger sign of lead toxicity sufficient to cause brain damage in children. Current professional opinion is that there is no safe level of blood lead and that levels under 5 µg/dl are also harmful to the brains of young children (Box 9.17). In 2012, the CDC Advisory Committee on Childhood Lead Poisoning recommended adoption of a BLL of 5 µg/dl as indicating an exposure risk. The new standard is considered to be a risk for impairment of cognitive ability and risks for cardiovascular, immunological, and endocrine disorders.

There may be no BLL which is harm free. Current recommendations include routine testing of infants and young

BOX 9.17 Lead Abatement in the USA, 1977–2009

Reduction of elevated blood lead levels (BLLs > 10 µg/dl) was one of the targets of Healthy People 2010. Studies in the USA based on the National Health and Nutrition Examination Survey (NHANES II) showed elevated BLLs in 88.2 percent of children aged 1–5 years in 1976–1980 (13.5 million children). The rate of elevated BLL fell to 8.6 percent in 1988–1991 (1.7 million children), 4.4 percent in 1991–1994 (850,000 children), and 2.2 percent in 1999–2000 (434,000 children). The lower level accepted as a marker by the Centers for Disease Control and Prevention (CDC) was reduced to < 5 µg/l in May 2012.

The reduction in prevalence of elevated BLL was due to a number of factors, including:

- reduction in use of lead in gasoline since 1976
- reduced use of food and soft drink cans containing lead solder
- reduced use of lead-based house paint
- national standards for lead exposure in industry
- ban on use of lead soldering on household plumbing
- screening of children as part of routine child care and intervention where elevated BLLs are found
- lead abatement by county health departments through removal of lead-based paint in older housing
- increased provider and parental awareness of lead-induced permanent brain damage hazard
- strong positions of the CDC, American Academy of Pediatrics, state and county health departments, and child advocacy organizations
- increased public awareness
- regulation and elimination of lead paint on child toys
- reduction of house lead paint exposure by removal, painting over, and aluminum covers. Lead prevention has high priority in US worker and child preventive care but is not emphasized in Europe or international programs.

Sources: Centers for Disease Control and Prevention. *Lead* [updated 10 August 2012]. Atlanta, GA: CDC. Available at: <http://www.cdc.gov/nceh/lead/> [Accessed 17 August 2012].

Agency for Toxic Substances and Disease Registry [updated 14 August 2012]. Atlanta, GA: ATSDR. Available at: <http://www.atsdr.cdc.gov/> [Accessed 15 August 2012].

children as well as exposed workers, along with environmental measures to reduce emission levels and industrial or home use of lead or lead-containing products. This topic has received a lot of attention in the USA and Canada, but less in other countries. CDC lead control programs have targets of eliminating elevated BLLs in the USA. This program focuses on assisting states and municipalities in lead poisoning prevention programs. The WHO recommends preventive measures including:

- environmental standards that remove lead from gasoline, paint, and plumbing
- replacement of lead pipes; where they cannot be removed, cold water should be flushed through in the morning before drinking

BOX 9.18 Bisphenol A and Heart Disease

Increasing evidence suggests that bisphenol A (BPA) may play a role in the development of heart disease and diabetes. Most commonly recognized as a component in food and beverage packaging such as plastic, BPA is problematic as it is classified as an endocrine-disrupting chemical. Results from the 2003–2004 and 2005–2006 NHANES, or the National Health and Nutrition Examination Survey conducted in the USA, indicate that elevated urinary BPA levels are correlated with heart disease.

In addition to food packaging, further sources of BPA include drinking water, dental sealants, and household dust. Polycarbonate, commonly used to strengthen plastics and reusable bottles, also contains BPA. When heat is applied to the plastic (such as containers or water bottles), the BPA typically is released. A UK researcher on this topic estimates that globally, 5 billion people are ingesting BPA.

A causal association exposure and health outcome of BPA and coronary artery disease cannot be established based on NHANES, which are cross-sectional in nature. A case–control study in the UK investigated baseline urinary BPA levels of participants diagnosed with cardiovascular disease, and compared them with the BPA levels of participants who did not have the outcome (i.e., did not develop heart disease). This study indicated an 11 percent increase in the likelihood of acquiring heart disease with each standard-deviation elevation in levels of urinary BPA.

The direct risk of BPA to humans is still unclear and controversial. However, increasing evidence suggests that environmental BPA exposure may be harmful to behavioral and other effects in children (Rochester 2013).

Sources: Lang IA, Galloway TS, Scarlett A, Henley WE, Depledge M, Wallace RB, Melzer D. Association of urinary bisphenol A concentration with medical disorders and laboratory abnormalities in adults. *JAMA* 2008;300:1303–10. Available at: <http://jama.jamanetwork.com/article.aspx?articleid=182571> [Accessed 17 August 2012].

Melzer D, Rice NE, Lewis C, Henley WE, Galloway TS. Association of urinary bisphenol A concentration with heart disease evidence from NHANES 2003/06. *PLoS ONE* 2010;5:e867. Available at: <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0008673> [Accessed 16 August 2012].

- enforcement of occupational health standards
- surveillance of potentially exposed population groups, especially vulnerable ones (young children, pregnant women, workers)
- water treatment
- removing lead solder from food cans
- use of lead-free paint in homes
- screening of children for BLLs over acceptable limits and referral for medical care as necessary.

The health-based guideline for lead in drinking water is 0.1 mg/l (WHO, 1993). If high levels are detected in a supply, alternative supplies or bottled water may be necessary to protect young children.

Scientists continue to discover new chemicals with potential for harmful effects on human health. Many hazardous substances are found in common everyday items, as exemplified by bisphenol A and its possible association with heart disease (Box 9.18).

AGRICULTURAL AND ENVIRONMENTAL HAZARDS

Pesticide and herbicide use to increase agricultural production is a worldwide phenomenon. Resistance to widely used chemicals has developed, and consequently, there is a continuing search for new chemicals. Excess use affects the ecosystem by the buildup of pesticides in the food chain and in groundwater, and the long-term effects may be serious.

Short-term exposure to agricultural chemicals may result in acute poisoning, especially in developing countries, where it is estimated to affect some 3 million people with 220,000 deaths annually. Suspected concentration of pesticides in breast fat tissues may be linked with excess breast cancer risk. Pesticide use in North America and the former Soviet countries is high but has declined since the 1980s, while it is increasing in Western Europe. Widespread use of pesticides in developing countries is often poorly supervised, and pesticide poisoning episodes are common.

The use of herbicides and pesticides within the recommended limits of the *Codex Alimentarius* (joint foods standards manual of the Food and Agriculture Organization, or FAO, and the WHO) and methods recommended by the International Code of Conduct on the Distribution and Use of Pesticides are considered safe. Current recommended practice is to reduce the amounts of pesticide and herbicide use, accompanied by care and safe use and storage practices to reduce the chance of acute poisonings. Alternative agricultural methods, using few or no chemicals, are the subject of wide research and experimentation.

AIR POLLUTION

The External Environment

Air pollution is contamination of the air by smoke, solid material, or chemicals that cause health and ecological damage to the community and the environment. It includes the oxides of sulfur and nitrogen spread locally and over long distances, domestically and internationally. The effects are increasingly important as the demand for and use of fossil fuels have grown for the internal combustion engine, heating, and power generation. Coal fuel used in homes created the terrible air pollution of nineteenth- and early twentieth-century London. In his classic novel *The Jungle*, Upton Sinclair described air pollution in Chicago in the early part of the twentieth century (Box 9.19). Such levels of pollution have subsided since the 1950s with the reduction of brown soft coal use in individual homes in most industrialized countries, but remain common in many mid-level developing countries. Use of coal-fueled energy plants in Central and Eastern Europe has created a gray zone of air pollution carried over long distances, destroying forests, creating serious damage to the human environment, and presenting health hazards to large population groups. Similarly, extensive damage has occurred in Canadian forests from acid rain originating in the USA.

Large modern fossil fuel plants built near population centers may use high chimneys to disperse the effluent. This reduces exposure of the adjacent population but contributes to long-distance pollutant effects, carrying sulfur and nitrogen oxides to forests and bodies of water, and creating sulfuric and nitric acid or acid rain. Acid precipitation affects rivers, streams, and lakes, many already burdened with sewage effluent and pesticide runoff, damaging the ecosystem and animal and plant life. The effects on human health are not easily measurable in a directly attributable way, but environmental damage affects the quality of life. International transmission of environmental damage is seen in nearly a quarter of Europe's forests from acid rain originating in Eastern European countries with poor emission control standards.

BOX 9.19 Upton Sinclair – *The Jungle*

“A full hour before the party reached the city they had begun to note the perplexing change in the atmosphere. It grew darker all the time, and upon the earth the grass seemed to grow less green. Every minute as the train sped on, the colors of things became dingier; the fields were grown parched and yellow, the landscape hideous and bare. And along with the thickening smoke, they began to notice another circumstance, a strange, pungent odor It was now no longer something far off and faint, that you caught in whiffs; you could literally taste it as well as smell it.”

Source: Sinclair U. *The jungle*. New York: Airmont; 1905.

The range of damage measured by the percentage of dead and dying trees varies from over 24 percent in Central and Western European countries (Denmark, Norway, the Netherlands, and Germany) to over 50 percent in some Eastern European countries (the Czech Republic and Poland). Environmental studies, primarily conducted in the early and mid-1970s, demonstrated that air pollutants are capable of traveling several thousands of kilometers. Thus, the harmful pollutants may accumulate and cause damage at a distance far from the original source of air pollution. International collaboration was imperative in developing solutions for large-scale environmental issues.

In the 1979 Convention on Long-Range Transboundary Pollution, European states agreed to reduce emissions that could cross international boundaries by 30 percent by 1993. This convention strengthened the development of international environmental law with a foundation to control and minimize the risk to human health as a result of transboundary air pollution. This represents the first legal tool concerning air pollution on an extensive regional level. Further, it provides a mechanism to limit and gradually reduce and prevent local and long-range transboundary air pollution. Cooperation includes developing policies and strategies to combat the discharge of air pollutants through exchanges of information, consultation, research, and monitoring. Studies are underway on the applicability of these standards to countries of Eastern Europe and Central Asia.

Air pollutants can enter the food chain by contaminating fish, fowl, and livestock. Changes in the acidity of water can create further harmful effects by corrosion of water pipes, affecting the lead, mercury, aluminum, cadmium, or copper content of drinking water. Acidified metals may cause chronic conditions such as chronic obstructive pulmonary disease (COPD) and asthma as well as specific chemical toxicity. Toxicity levels are difficult to measure epidemiologically; regulation of source emissions is set as a proxy measure for preventable exposure to unhealthy contaminants.

Particulate matter in air pollution has both physical and chemical effects on the nasopharynx and respiratory tract. Excess cancer of the respiratory tract and COPD can be demonstrated in exposed populations. A variety of syndromes is associated with specific respiratory irritants, such as coal dust (miner's lung) and cotton dust (byssinosis), among exposed occupational groups. A study of regional cancer rates in Israel in the 1980s showed an excess of cancers of the nasopharynx and respiratory tract in people living in an area exposed to high levels of silicate materials in emissions from a local cement plant. Geographic cancer epidemiology in the UK shows higher levels of many diseases in terms of standardized mortality rates (SMRs) in urban or other polluted areas in Britain, correlating excess morbidity with excess air pollution (see Chapter 3).

The London “killer fog” incident in 1952, implicated in up to 4000 deaths, raised international concern over the

deadly effects of critical levels of pollution as well as the long-term effects. In Britain, this led to controls on the use of soft coals for home fires and a gradual reduction in the Victorian levels of smog that had fouled ambient air quality in British industrial and commercial centers. A similar inversion in 1948 in Donora, Pennsylvania, affected over 40 percent of the population of 14,000, with 20 deaths. A smog crisis in New York City in 1966 occurred a month before the third National Conference on Air Pollution, followed by a series of smog crises in California.

Localized air pollution is largely generated by automobiles and general industry. Pollution of urban areas with lead, sulfur dioxide (SO₂), and nitric oxide (NO) has been reduced where catalytic converters and unleaded gasoline are compulsory. However, the beneficial effect is reduced simply by the increase in the number of automobiles, as shown in the southern California experience. During the 1960s and 1970s, there was a growing sense of crisis in environmental pollution in the USA. Until the 1970s, solid and liquid industrial wastes were dumped or discharged indiscriminately, with volatile chemicals contaminating water sources and the air. Pollution of lakes and rivers and poor air quality in the cities led to a series of federal legislative acts, including the Motor Vehicle Air Control Act of 1967, the Air Quality Act of 1967, the more effective Clean Air Act of 1970, the Clean Water Act of 1977, the Safe Drinking Water Act of 1974 (amended 1996), and the Water Quality Act of 1987, as well as the establishment of the EPA in 1970.

Traffic congestion in modern cities exposes car occupants and pedestrians to exhaust fumes containing particulate matter and air pollutants. Pollutants may act to compound the ill-effects of other risk factors such as smoking. Los Angeles is subject to heavy pollution and temperature inversions, producing harsh conditions for those prone to chronic bronchitis, asthma, and COPD. A study in Los Angeles showed that an increase of 10 parts per million of carbon monoxide (CO) levels in the air was associated with a 37 percent increase in hospital admissions. Action by state and local authorities to enact more stringent car and industrial emission standards, and replace high emission trucks and buses, has brought Los Angeles' air pollution levels down and continue to work to further the provisions of the US federal Clean Air Act. The problems of air pollution are widespread in urban areas of mid-level and low-income level countries; increasingly crowded and automobile-oriented cities such as Mexico City, Beijing, and Mumbai have poor standards of pollution control and serious air pollution levels.

Where the numbers of cars and trucks increase, but measures to control air quality standards are not implemented, pollution can have alarming effects on adult and child health. In children, asthma exacerbation and high BLLs can have serious detrimental effects on health. Among adults

with a predisposition to cardiovascular disease and respiratory tract damage, chemical and particulate pollutants can cause increased mortality. Carbon monoxide blocks the uptake of oxygen by red blood cells and can reduce the oxygen carrying capacity of blood. In vulnerable groups, such as children, the elderly, pregnant women, and the immunosuppressed, this can have serious deleterious effects on psychomotor function. Polycyclic hydrocarbons released from car emissions and other sources are carcinogens. Nitrogen oxides (NO_x) affect the terminal respiratory tract alveoli, increasing susceptibility to lower respiratory tract infection in children. Ozone (O₃) and secondary pollutants affect UV light absorption, increasing skin cancer incidence. Ozone can travel hundreds of kilometers, causing clinical effects close to and well away from the site of the traffic. Carbon dioxide affects global warming with potentially important effects on world climate and water supplies. The health and environmental effects of air pollutants pose severe challenges to the global community. The Organisation for Economic Co-operation and Development (OECD, 2012) reports that by 2050, air pollution will become the leading environmental cause of early death worldwide.

Emission control through regulation and new technology should be seen in the context of overall transportation policy. Policy in transportation has long-term effects in determining degrees of air pollution, land use, and trauma from motor vehicle crashes. A full accounting of the costs of morbidity and mortality associated with air pollution and traffic accidents should be included in cost-effectiveness studies of rail versus road transport, especially in crowded urban communities and in countries with limited land space.

The US Federal Clean Air Act of 1970 established air quality standards for major pollutants such as NO_x, CO, SO₂, O₃, asbestos, dioxin, and other toxic air contaminants. Improving enforcement, especially of automobile emissions, has led to improved air quality in many parts of the country. Though federally legislated, implementation is at the state level. Standards are set for ambient air quality, automobile emissions, and emission by stationary facilities, such as power plants and factories. Such standards are also being implemented in many other countries.

The Clean Air Act Amendments of 1990 listed 189 hazardous air pollutants (HAPs) for which Congress mandated the EPA to issue standards. These include asbestos, dioxin, diesel, and many other potentially toxic agents, including latex, which has been identified as a factor in causing asthma. The US Food and Drug Administration (FDA) is continuing to develop standards for other HAPs. The Clean Air Act as amended provides for state agencies to regulate local air districts.

The California Air Quality Management Board regulates regional air quality management boards (e.g., southern California) that carry out a certification process of local

industry. This board has powers to sanction changes in industrial practices in any given industry by attributing its component of ambient air pollution, with the potential for closing down an offending industry. As a result, California has been able to reduce air pollution dramatically since the mid-1980s, with only one major smog alert occurring in 1997 compared to 66 in 1987 in Los Angeles. The California Air Resources Board estimates that fine particle pollution causes 9000 excess premature deaths annually through its effects on pre-existing ischemic heart and chronic respiratory disease, and indicates the benefits of meeting national ambient air quality standards. Air pollutants are linked with excess hospitalizations of children for asthma-related conditions.

Beginning in the late 1990s, technological innovations have become standard in some new automobiles, thus further reducing emissions and increasing the mileage per gallon of gasoline. Other innovations incorporate hydrogen fuel cells and hybrid and electric vehicles that will release nearly zero pollutants at the point of use, and may contribute to a reduction in cardiovascular and respiratory disease deaths due to fine particle exposure.

The goal of the US Clean Air Act is to reduce the proportion of people exposed to air that does not meet the standards. Ozone affects 43 percent, particulate matter 12 percent, carbon monoxide 20 percent, nitrogen dioxide and sulfur dioxide 2 percent, and lead less than 1 percent of the population. It is estimated that improvements in healthy air have prevented 160,000 premature deaths. The estimated benefits of reduced air pollution are as many as 230,000 fewer deaths, 200,000 fewer heart attacks, and 2.4 million fewer asthma attacks in the next decade (Welker-Hood et al., 2011). Collaboration among multiple countries and responses to air pollution on an international level are exemplified in the Montreal Protocol (Box 9.20) and the United Nations Framework Convention on Climate Change (UNFCCC) (Box 9.21).

Diesel air pollutants became the subject of scrutiny by the state Air Resources Board, which carried out a meta-analysis and defined diesel pollution as a health hazard. This decision requires use of best available control technology (BACT) to reduce emissions from the defined “acceptable risk” of 10 excess cases of cancer per million population. In the case of diesel emissions the excess rate was determined to be 100 times in excess of the acceptable rate. Industry opponents raise the specter of the tremendous economic effects of such decisions, but the BACT approach minimizes this potential harm to the economy. At the same time, the process of identifying the issue spurs industry to seek out technological solutions that are compatible with greater efficiency in the long run. Box 9.22 discusses the development of US regulations designed to reduce fine particle emission air pollution.

BOX 9.20 International Treaties to Protect the Ozone Layer in the Atmosphere

The high-altitude or stratospheric ozone layer of the air acts as a shield in the atmosphere that protects life on Earth by blocking the sun’s harmful ultraviolet (UV) radiation, which affects humans and ecosystems. During the 1980s, scientists observed that the stratospheric ozone layer was getting thinner over Antarctica (the “ozone hole”). A series of conventions and amendments produced a high degree of international acceptance and implementation of measures to reduce the use of chemical agents that adversely affected the ozone layer.

The Vienna Convention on the Protection of the Ozone Layer in 1985 was the precursor to the Montreal Protocol. The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in 1987. This treaty is the basis on which Title VI of the US Clean Air Act was established. The Montreal Protocol was updated by a series of conferences: London Amendment (1990), Copenhagen Amendment (1992), Montreal Amendment (1997), Beijing Amendment (1999), and Vienna (2000).

All UN recognized nations have ratified the treaty and continue to phase out the production of chemicals that deplete the ozone layer while searching for ozone-friendly alternatives. A broad coalition developed and implemented effective approaches to ensure stratospheric ozone layer protection. By agreements of an Executive Committee, the key agencies involved were the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), United Nations Industrial Development Organization (UNIDO), and the World Bank.

Specific chemicals declared in the process include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs), but not all are banned or being reduced. Atmospheric concentrations of many of the important CFCs and related chlorinated hydrocarbons have either leveled off or decreased. Banning many chemicals and finding better alternatives and technologies has contributed to the process. The US Environmental Protection Agency has approved over 300 safe alternative chemicals to those which contribute to ozone depletion. The ozone layer has not grown thinner since 1998, but continued enforcement of the phasing out of ozone-depleting substances is vital to return the ozone layer to normal levels over the coming decades.

The Montreal Protocol process led to a broad coalition of governments, scientists, and others who work to develop effective approaches to protect human health and the global environment. Its adoption and implementation provide an approach to global cooperation in order to achieve global environmental protection. However, implementation by member nations is slow and variable.

Sources: Sarma K, Bankobeza G. *The Montreal Protocol on substances that deplete the ozone layer*. Nairobi: United Nations Environment Programme; 2000. Available at: <http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf> [Accessed 17 August 2012].

BOX 9.21 The Kyoto Accord and UNFCCC: The International Response to Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was created in 1992, when countries collaborated in an effort to join an international treaty to define actions needed to control increases in average global temperature and the resulting climate change.

By 1995, it became apparent to many country leaders that emission reduction provisions in the Convention were insufficient. Negotiations to strengthen the global response to climate change led to the adoption of the Kyoto Protocol.

The Kyoto Protocol legally binds developed countries to emission reduction targets. The Protocol's first commitment period started in 2008 and ran until 2012. In Durban, government Parties to the Kyoto Protocol made a decision to implement a second commitment period, from 2013 onwards, extending the first commitment by either 5 or 8 years.

There are currently 195 parties participating in the Convention. The UNFCCC supports all bodies involved in the international climate change negotiations, particularly the Conference of the Parties (COP) and each of its supporting institutions.

A complex global environmental issue, climate change carries with it consequences relating to all spheres of existence on this planet. It impacts and influences many underpinning continuous global challenges such as poverty, economic development, population growth, sustainable development, and resource management. Therefore, solutions to help mitigate these large-scale challenges require assistance from all disciplines and fields of research, and above all political commitment.

The central issue in the response to climate change lies in the need to reduce greenhouse gas emissions. In 2010, multiple governments reached an agreement that emissions must be reduced in order for global temperature increases to be limited to below 2°C.

Rio+20, the United Nations Conference on Sustainable Development held in June 2012, planned to address climate change, oceanography, fisheries, resource management (water, land), food security, and further issues of this nature. However, the conference representatives came to an agreement to switch the key issue to economic development. Thus, a major emphasis was put on poverty eradication, an underlying and complex issue involving a myriad of global environmental challenges.

Sources: Adapted from United Nations Meetings. Bonn: UN Framework Convention on Climate Change. Posted 2012. Available at: <http://unfccc.int/2860.php> [Accessed 15 August 2012].

United Nations. The future we want. Rio+20 United Nations Conference on Sustainable Development; 2012. Available at: <http://www.un.org/en/sustainablefuture/> and <http://www.uncsd2012.org/futurewewant.html> [Accessed 11 August 2012].

Methyl Tertiary Butyl Ether

Methyl tertiary butyl ether (MTBE) is a synthesis of methanol and isobutylene, developed as an additive to gasoline to improve octane performance. It was widely adopted in

the USA, especially in California, in place of ethanol used in other states. Ethanol is a farm product that was encouraged by the US Department of Agriculture as a new economic opportunity for farmers and a relatively non-toxic agent environmentally. Some gasoline producers opted to use MTBE instead, as it is produced and promoted by the chemical industry.

MTBE is a volatile, ether-based chemical agent that when present in drinking water imparts a bad taste. MTBE was adopted widely without adequate testing for potential toxic effects and has come under scrutiny. Evidence of carcinogenesis in rats raised concerns that MTBE may have the same effect in humans, especially drivers, gasoline station attendants, and refinery workers exposed to high levels. The effectiveness of MTBE in promoting clean burning of gasoline and reducing exhaust pollutants has also been questioned. MTBE has been found in 3.4 percent of water districts in California. Some 50 percent of drinking water wells in Santa Monica, California, were closed owing to MTBE contamination in 1995.

The MTBE case is an example of EPA-sanctioned use of a harmful chemical substance widely used in industrial settings as a gasoline additive, and therefore present in automobile emissions. It replaced a more environmentally safe substance from the farming industry even before environmental concerns brought the issue under public scrutiny. Since 1996, the American Public Health Association (APHA) has called on the FDA to ban MTBE as a hazardous chemical, to place restrictions on the use of gas-powered boats on lakes and rivers, to return to ethanol-based fuel additives, and to inspect underground storage facilities for gasoline to reduce leakage and contamination of groundwater. In 2000, the EPA included MTBE under the Toxic Substances Control Act and called for efforts to reduce MTBE contamination of ground and surface water supplies (EPA, 2007).

INDOOR POLLUTION**Effects of Indoor Air Pollution**

Contaminants within private dwellings may be a greater health hazard than external pollution. Housing is understood as a crucial factor influencing population health, as people generally spend a large portion of time inside their dwelling. According to studies, people spend about two-thirds of their time inside their house; however, this figure differs by populations and subgroups. Women, as well as vulnerable groups such as the elderly, children, and those who are ill, are particularly affected by indoor air pollution. Others, who are unemployed or rarely participate in external affairs, are also more affected. According to WHO data, use of household solid fuel contributes to indoor pollution, causing serious illness resulting in the premature death of almost

BOX 9.22 Reduction in Fine Particle Emissions: Air Pollution Standards in the USA

Since the Clean Air Act was enacted more than in 1970, pollution in the USA has been reduced while the population and economy have grown. The health benefits far exceed the costs of reducing pollution. Less pollution lower the risks of premature death and other serious health effects. Environmental damage from air pollution is reduced. New cars, trucks and non-road engines use state-of-the-art emission control technologies. New plants and factories install modern pollution control technology. Power plants have cut emissions that cause acid rain and harm public health. Interstate air pollution has been reduced. Mobile and industrial pollution sources release much less toxic pollution to the air than in 1990. Actions to protect the ozone layer are saving millions of people from skin cancers and cataracts. National parks are clearer due to reductions in pollution-caused haze. EPA has taken initial steps to limit emissions that cause climate change and ocean acidification. The Act prompted deployment of clean technologies, with impetus for technology innovations that reduce emissions and control costs (EPA, 2012, 2013).

These regulations require states to significantly improve air quality by reducing power plant emissions that are partially responsible for ozone and/or fine particle pollution in other states. CSAPR identifies 28 states that are required to reduce annual SO₂ emissions, annual nitrogen oxide (NO_x) emissions and/or ozone-season NO_x emissions. Together, these substantial reductions play a meaningful role in attaining the 1997 ozone and fine particle and 2006 fine particle NAAQS, thus replacing EPA's 2005 Clean Air Interstate Rule (CAIR). The new regulations will improve air quality throughout the eastern half of the USA, helping states to achieve national clean air standards.

Similar to all health regulations, the purpose of CSAPR and its implementation is to improve a population's health outcomes. Expected health benefits directly resulting from CSAPR include reduced premature mortality by approximately 13,000–34,000 cases. Moreover, experts predict that the following number of cases will be averted due to CSAPR: 15,000

non-fatal heart attacks, 19,000 emergency room visits, 420,000 cases of upper and lower respiratory illnesses, and 400,000 cases of asthma attacks. The benefits include avoiding loss of 1.8 million days of work or school. This will result in achieving hundreds of billions of dollars in public health benefits, and will yield US\$120–280 billion in annual health and environmental benefits in 2014. Scientists predict that the new air pollution ruling will improve visibility in national and state parks, as well as tighten protection for sensitive ecosystems, including Adirondack lakes and Appalachian streams, coastal waters and estuaries, and forests.

The US\$800 million annual projected costs of this rule in 2014, as well as the approximately US\$1.6 billion per year in capital investments already advancing due to CAIR, are making progress to improve air quality for over 240 million Americans. Moreover, the emission reductions anticipated to result from EPA's newly finalized Mercury and Air Toxics Standards (MATS) are not included in the estimated emission reductions from the CSPA; once those standards are implemented, SO₂ emissions from the power sector are likely to be reduced even further. More recently, since April 2012, the EPA has issued new standards under the Clean Air Act. These regulations pertain to hydraulic fracturing oil and gas systems, thus affecting the oil and gas industry. Anticipated outcomes of the standards include not only a reduction in groundwater pollution, but also a reduction in hazardous methane, benzene, and other volatile organic compound emissions by 95 percent.

Sources: Environmental Protection Agency. *Air pollution and the Clean Air Act*. Last updated 16 August 2013. Available at: <http://www.epa.gov/air/caa/> [Accessed 22.12.2013].

Environmental Protection Agency. *Progress Cleaning the Air and Improving People's Health* <http://www.epa.gov/air/caa/progress.html> [Accessed 22.12.2013].

Environmental Protection Agency. *Oil and natural gas air pollution standards* [updated 18 April 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/airquality/oilandgas/index.html> [Accessed 17 August 2012].

2 billion people. Likewise, COPD, resulting from exposure to indoor air pollution, is responsible for killing over 1 million people annually.

Increased insulation, window layers, sealed doors, and smoking all contribute to increased concentrations of indoor pollutants, including benzene, formaldehyde, carbon monoxide, and radon gas, as well as bacteria, fungi, and viruses. Smoking is a widespread habit, and passive smoking, or inhalation of smoke generated by other people, is a long-term health hazard.

Wood and its waste products, vegetable matter, and animal dung are sometimes referred to as *bamboo fuels*. These are less efficient than fossil fuels in terms of heat produced per unit mass. Approximately half of the world's population depends on such fuels for their daily needs. These fuels are used extensively in rural areas of developing countries because they are cheap and widely available, but they require much time to gather. Moreover, they lead

to deforestation with other damage to the environment. Primitive stoves are often used, creating fire hazards and high levels of continuous daily indoor pollution due to poor ventilation. The dangers associated with use of bamboo fuels include fires, smoke inhalation, and chronic indoor pollution. These fuels release many chemical compounds including suspended particulate matter, carbon monoxide, nitrogen and sulfur oxides, aldehydes, hydrocarbons, benzene, phenols, and complex hydrocarbons.

Women in India show high rates of right heart failure (cor pulmonale) from the fumes released from cooking stoves. Technological development of more efficient wood stoves would reduce the problem; however, other forms of energy are more efficient and less damaging to health in the home and to the environment. Currently, approximately 3 billion people are still using solid fuels in open fires or leaky stoves to cook or warm their houses. These methods generate pollutants and soot pieces that can enter

deep into a person's lungs. Serious health consequences of these outdated methods and the impure air they produce include pneumonia, COPD, lung cancer, and lung and airway inflammation. Further research suggests that indoor air pollution may be associated with low birth weight, the development of tuberculosis, and ischemic heart disease. As one would expect, indoor air pollution primarily affects poor populations and those living in developing countries. The following statement demonstrates the severity of the problem: in the homes of some families living in developing countries, women who cook for three hours per day can be exposed to equivalent levels of benzo(a)pyrene as one would obtain from smoking two packs of cigarettes daily.

The UN Foundation, in collaboration with the WHO and other agencies, has established the Global Alliance for Clean Cookstoves. The Alliance is working to encourage better quality biomass cookstoves to significantly diminish indoor air pollution. To advance in this program, WHO established a household energy database, used to evaluate the world's progress in the conversion to cleaner fuels and safer stoves. This database will allow for monitoring and evaluation of disease burden and important health outcomes. Progress made in this area of health will influence the success of multiple MDGs. It will play a role in reducing child mortality (MDG4), and improving maternal health (MDG5) and gender equality (MDG3); furthermore, improved sources of household energy will influence environmental sustainability (MDG7).

Research conducted by the WHO on housing conditions in Europe validates the notion that insufficient housing standards are correlated with increased risk of respiratory diseases, such as asthma, lung infections, and allergies. These health outcomes are likely to be due to dampness within a house, which offers a welcoming environment for agents that may trigger respiratory diseases, such as roaches, mites, viruses, and molds. Indoor pollution from materials used in construction is a serious health problem. Asbestos in the home may contribute to mesothelioma and lung cancer. Lead paint in the home increases the hazard of lead toxicity among young children, which is associated with brain damage. Unsafely packaged household chemical solvents and mold in the home contribute to poisonings as well as asthma morbidity and mortality. Overcrowding and insufficient hygiene are further hazards within the home. Studies demonstrate an association between low indoor temperature and suboptimal health status, specifically in relation to cardiovascular disease. Past interventions focused on modifying housing through thermal improvement have proven to substantially improve mental health. Furthermore, the temperatures in households of low-income populations tend to be more extreme and unbearable owing to inadequate insulation or no air conditioning. Consequently, health professionals have recognized a link between substandard living conditions (specifically defined by thermal inefficiency) and elevated winter or summer mortality rates.

Indoor air pollution is a very serious, widespread public health problem, affecting some populations more than others. Globally, it is the most impoverished people, those susceptible to countless other health issues who suffer the most. Interventions, policy changes, and global support should be a priority in establishing and achieving the goal of reducing exposure to indoor air pollution, while finding alternative, cleaner, safer, methods to meet a population's cultural needs and energy requirements.

Radon Gas

Radon is a very heavy gas that produces harmful alpha particles as a byproduct. Radon originates in the natural radioactive decay of uranium from soil and rocks such as granite, shale, and phosphate, and is present as a gas in ground crevices, dissolved water, or dispersed open air. It seeps into homes via basement cracks and into well water and point sources. Radon was first detected in homes in the USA in 1984 near Philadelphia. Early investigations showed in-home radiation exposure as high as the equivalent of 455,000 chest X-rays. Further investigation revealed that sections of eastern Pennsylvania, New Jersey, and New York lie over uranium-rich geological formations that result in high levels of radon contamination.

The US EPA in 1988 advised that all homes be checked for radon levels. Inexpensive home radon detectors are available that meet EPA standards. In 1988, the EPA estimated that radon contributes to between 7000 and 30,000 cases of lung cancer per year, or up to 10 percent of all lung cancer deaths in the USA. In 2009, the WHO estimated that 5–15 percent of all lung cancers are caused by radon, which is the primary cause of lung cancer among non-smokers. Radon-induced cancers are caused by low and moderate levels of radon as in the home environment. Hundreds of thousands of US citizens receive as much radiation as did people living near the Chernobyl plant at the time of the nuclear accident in 1986. Cigarette smoking has a synergistic effect, enhancing the radon-related risk of lung cancer by a factor of 10. Radon reduction can be carried out in high-risk homes by carefully planned sealing of identified sources, ventilation, and fans for high radon basements.

Outdoor–Indoor Pollutants

Carbon monoxide, nitrogen oxides, chemicals, and particulate matter are common outdoor pollutants that can accumulate in homes with kerosene and wood stoves, attached automobile garages, or cigarette use. Passive smoking can expose the non-smoker to benzene and other carcinogens. Formaldehyde is produced from insulation material, plywood, and floor coverings, especially in mobile homes. Chemical fumes from household products, such as disinfectants, solvents, hair sprays, furniture polish, and dry cleaning solvent, also pollute the home atmosphere and can potentially cause childhood poisonings.

Carbon monoxide poisoning from home heaters where there is inadequate ventilation causes 100 deaths per year in the UK. Some deaths from carbon monoxide poisoning may be attributed to heart disease and can only be diagnosed affirmatively by measurement of carbon monoxide in the air or blood carboxyhemoglobin levels.

Biological Pollutants

Bacteria and fungal spores can enter a building and infect its inhabitants, usually through the air conditioning or ventilation system, as is the case with Legionnaires' disease (see Chapter 4). Occupants of a building may suffer from allergies due to fungal spores, mites, animal dander, and feces of roaches or mites. These allergies are more likely to occur in buildings using humidifiers or vaporizers with stagnant

water, which favor bacterial and fungal growth. Sick building syndrome is discussed in [Box 9.23](#).

Built Environment and Health

A Healthy City, as defined in the Zagreb Declaration (WHO, 2009), is a city for all its citizens: inclusive, supportive, sensitive and responsive to their diverse needs and expectations. It provides conditions and opportunities that encourage, enable and support healthy lifestyles for people of all social groups and ages. It offers a physical and built environment that encourages, enables and supports health, recreation and well-being, safety, social interaction, accessibility and mobility, and a sense of pride and cultural identity, and is responsive to the needs of all its citizens.

BOX 9.23 Sick Building Syndrome

Recurrent respiratory infections, wheezing, fatigue, dizziness, headache, eye and nose irritation: when these symptoms affect people working inside a specific building, the term used to describe this condition is *sick building syndrome*.

Although studied for decades, it is still a poorly understood condition, as scientists have been unable to pinpoint one single cause. The consensus is that it is a combination of various risk factors that lead to people experiencing symptoms of sick building syndrome. Potential factors include poor ventilation, low humidity, dramatic changes in temperature throughout the day, airborne pollutants (dust, fungal spores), and chemical pollutants, such as cleaning materials. Poor levels of cleanliness in the work environment may play a role in employees developing symptoms of sick building syndrome. Poor ventilation systems may fail to provide adequate fresh air relief from microbiological pollution, formaldehyde in furniture, ozone emissions from photocopying machines, and cigarette smoke.

The common symptoms listed above typically improve or disappear after an affected person has left the building, that is, once the person is no longer surrounded by the exposure. While sick building syndrome is an increasing occupational problem, there are preventive and control measures that can and should be implemented. Some of the many strategies include elimination or adaptation of the pollutant sources, maintaining adequate waterproofing, removing water-stained ceiling and flooring, and keeping products such as paints, solvents, and adhesives tightly enclosed and in highly ventilated areas. Measuring air distribution and ventilation levels is also critical. Building codes should specify minimum levels of outside air admission; acceptable levels of oxygen, carbon monoxide, and carbon dioxide; odor dilution; and adequacy of ventilation equipment. Further crucial factors include education and communication to advance the process of air quality programs, as well as prohibition of smoking in the workplace.

Although the condition is not well understood and an affected individual can experience a wide variety of symptoms, a set of elements is associated with a higher prevalence of sick

building syndrome. Host factors include being female and working in a job that is considered lower in building hierarchy (a more menial job), which increases risk of being affected by sick building syndrome. Exposure to paper dust, office dust, cigarette smoke, and increased use of computers are common factors. The likelihood of developing this syndrome increases with high indoor temperature (>23°C in air-conditioned buildings), low fresh air ventilation, poor individual control of lighting and temperature, excessive use of air conditioning, water damage, inadequate building service maintenance, and insufficient levels of cleanliness.

Depending on the severity of a worker's symptoms, employees suffering from sick building syndrome are likely to have economic consequences. Maintaining a healthy, safe, comfortable environment comes at a cost; however, so does low worker productivity and satisfaction. A study conducted in Switzerland showed that, compared with workers in air-conditioned offices, those who work in naturally ventilated buildings typically take less sickness absence. Moreover, a study carried out in the Netherlands examined the number of days of missed work due to sickness and whether a worker was given the opportunity to control his or her own office environment. The researchers found that among office workers who were given the freedom to control their own environment, 34 percent less sick days were taken.

It is crucial that employers respond efficiently and effectively to their workers' complaints, as each individual deserves to work in a safe, healthy, clean environment. A substantial portion of many people's lives is spent in an office building; therefore, an individual's level of health is very much influenced by his or her working conditions.

Sources: National Health Service. Sick building syndrome [updated 29 October 2010]. UK: NHS. Available at: <http://www.nhs.uk/conditions/Sick-building-syndrome/Pages/Introduction.aspx> [Accessed 17 August 2012]. Joshi SM. The sick building syndrome. *Indian J Occup Environ Med* 2008;12:61–4. Available at: <http://www.ijoem.com/article.asp?issn=0019-5278;year=2008;volume=12;issue=2;page=61;epage=64;aulast=Joshi> [Accessed 17 August 2012].

The public health aspects of the built environment include the physical parts of places where people live and work. These include homes, buildings, streets, open spaces, and infrastructure to provide recreation, commerce, facilities for physical activities, such as jogging, bicycle paths, workout equipment to promote physical activity and leisure, and access to well-stocked grocery and fruit and vegetable supplies. These amenities are meant to promote physical activity, reduce sedentary habits, and promote healthful eating and recreation. Roads, industry, and commerce zoning regulation are part of Healthy Cities, and public health can be improved by far-sighted local authority planning and implementation. Alleviation of industrial and air pollution from power plants and roads is vital to improving habitation in urban settings. In developing countries, the environment of urban slums, without adequate safe water supply or sewage and garbage disposal, promotes illness and inequality that healthful urban environments can do much to alleviate.

In recent years this healthy urban environment approach has expanded to include open space and rooftop gardening for urban dwellers to grow fresh vegetables, and for recreational and economic benefit. This is now common practice in cities such as New York City, London, and Hong Kong. It may be especially important for the urban poor with limited access to stores selling fresh fruit and vegetables, making healthy eating difficult; and private gardening can make a huge difference to a struggling family.

HAZARDOUS OR TOXIC WASTES

Toxic materials used in industrial processes can cause ill-effects in workers exposed to the material at the site of production and in storage, transport, and use of the materials. They can also cause harmful effects to people living near the material, as well to the environment. Case studies of serious environmental pollutants and their effects on health demonstrate the problems involved.

Hazardous wastes are defined as any discarded material that may pose a substantial threat to human health or the environment when improperly handled. They include toxic wastes such as arsenic, heavy metals, and pesticides which can cause acute or long-term health problems. Ignitable wastes include organic solvents, oils, plasticizers, paint waste, and corrosive wastes (with a pH of <2 or >12.5) which can eat away metal containers or living tissue. Reactive wastes include obsolete munitions and acids that react with water or air to produce explosions or toxic fumes. Radioactive and infectious wastes from hospitals are also hazardous to public health. Hospital wastes took on new importance with the dangers of transmission of hepatitis B, HIV, and drug-resistant microorganisms in contaminated materials. The problem caught worldwide attention in the late 1980s when waste material from hospitals washed on

to beaches in the USA. [Box 9.24](#) presents information on hospital and health care facility waste.

Prevention and waste site remedies have gained wide attention by industry as well as federal, state, and local government. Media and public concern was generated by episodes such as the Love Canal in the late 1970s, which served to mobilize public awareness of environmental health in the USA. In the 1890s, Mr. William T. Love built a canal bypassing Niagara Falls with the intent of building an industrial city using inexpensive hydroelectric power. The project failed and the canal was abandoned and the land sold at public auction. In 1942, the Hooker Chemical Company (subsidiary of the Occidental Petroleum Co.) received permission to use the canal to dump chemicals from its several plants in the area. Up to 1953, when it was covered by landfill, 21,000 tons of chemical wastes (acids, alkalis, solvents, chlorinated hydrocarbons, etc.) were disposed of at the site. Despite warnings, the land was sold and over 1000 homes, apartments, and schools were constructed along the covered canal.

Beginning in the 1950s, local residents complained of foul odors and chemicals oozing from the covered canal. In 1978, pressure from local congressmen and news media prompted investigation by the EPA and the New York State Department of Health. Over 200 different chemicals were identified, including dioxin and 12 known or suspected carcinogens, mutagens, and teratogens. The New York State Commissioner of Health proclaimed an imminent health peril and called for evacuation of pregnant women and children under the age of 2. Over 1000 families were evacuated and 300 homes demolished at public expense. Work at the site to contain the chemicals and prevent seepage and groundwater contamination cost over US\$180 million. An initial investment of US\$2 million by the Hooker Chemical Company at the time of the disposal could have prevented the damage to health and associated costs.

Epidemiological studies of the exposed residents showed that they experienced statistically significant elevated rates of miscarriage, birth defects, and chromosomal abnormalities, but the studies' methods and conclusions remain controversial. This episode focused national concern on the approximately 16,000 hazardous waste sites throughout the USA. In 1980, Congress established a superfund program, funded by federal tax on the chemical and petroleum industries, to locate, investigate, and clean up the worst sites in the country.

Minimata Disease

Minimata disease is a chronic neurological disorder caused by methyl mercury, a heavy metal with many industrial uses. The disease was first reported near Minimata Bay in Japan in 1968, when mercury oxide was being discharged from a chemical plant into the waters

BOX 9.24 Hospital and Health Care Waste

Medical facilities and health providers use countless tools, drugs, vaccines, dressings, needles, and syringes in patient care and performing procedures, generating massive amounts of waste. Waste and its by-products can be classified into eight different categories: infectious waste, pathological waste, sharps, chemicals, pharmaceuticals, genotoxic waste, radioactive waste, and heavy metals. The World Health Organization (WHO) estimates that 80 percent of the total waste produced from health care functions is general waste, similar to domestic waste, while 20 percent is classified as hazardous material, which may be infectious or toxic, or possess radioactive properties.

Infectious waste includes material contaminated with blood, cultures of infectious agents, and contaminated products such as bandages and swabs. Pathological waste consists of identifiable body parts, while sharps are syringes, needles, and disposable tools, such as scalpels and blades. Common chemical forms of waste include mercury and various disinfectants, and pharmaceutical waste consists of expired or contaminated drugs, as well as vaccines and sera. Certain forms of waste can be especially dangerous and require very careful handling, in particular, genotoxic waste, as well as mutagenic, teratogenic, and carcinogenic materials, such as cytotoxic drugs used for cancer treatment, and radioactive diagnostic material.

High-income countries produce on average 0.5 kg of hazardous waste per hospital bed each day, while low-income countries typically produce 0.2 kg. In low-income countries it is often the case that no distinction is made between hazardous and non-hazardous waste generated from health care; thus, the true amount of hazardous waste is likely to be significantly greater than the estimated figure. Globally, approximately 16,000 million injections are delivered annually. Not all syringes are disposed of appropriately, thus the risk of infection and possibility of reuse emerges. The WHO in 2000 estimated that 21 million cases of hepatitis B virus, 2 million cases of hepatitis C, and 260,000 HIV infections resulted worldwide

from injections using contaminated syringes. Reuse of disposable syringes is a dangerous and common practice, especially in some African, Asian, and Central and Eastern European countries.

In the USA, most infectious medical waste (over 90 percent) is disposed of through incineration. In 1997, the Environmental Protection Agency (EPA) announced regulations to control levels of emissions released from medical waste incinerators. Although incineration is the primary form of disposing of medical and health care waste, when incinerators are unavailable the waste can be taken to solid waste landfill depots, where safe packaging and proper precautions are taken to avoid contact with the public. Other alternatives to incineration include thermal treatment, steam sterilization, and chemical-mechanical systems.

Substandard management of medical waste can result in health workers, waste handlers, and patients being exposed to the risks of infection, toxic materials, and injuries. Further hazards include environmental damage, which affects the entire community. As WHO has declared, it is imperative that products of health care waste, including unused medications, are segregated immediately after use, adequately treated, and cautiously disposed of. Home health care waste should also be attended with safety in mind for caregivers, patients, families, neighbors, and the community.

Sources: Environmental Protection Agency. *Medical waste frequent questions* [updated 24 July 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/osw/nonhaz/industrial/medical/mwfaq.htm> [Accessed 17 August 2012].

Environmental Protection Authority. *Guidelines: medical waste – storage, transport and disposal*. South Australia: Environmental Protection Authority; 2003. Available at: http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/guide_medical.pdf [Accessed 15 August 2012].

World Health Organization. *Waste from health care activities* [updated November 2011]. Geneva: WHO. Available at: <http://www.who.int/media-centre/factsheets/fs253/en/index.html> [Accessed 17 August 2012].

World Health Organization. *Medical waste* [updated 2012]. Geneva: WHO. Available at: http://www.who.int/topics/medical_waste/en/ [Accessed 17 August 2012].

of the bay. It was converted to an organic form, methyl mercury, by organisms in the mud and slime of the bay floor. Mercury poisoning of fish is a recurrent phenomenon where industrial wastes discharged into rivers, lakes, and the sea enter the food chain, and humans are affected through fish consumption. As of March 2001, 2265 victims had been officially recognized (1784 of whom had died) and over 10,000 had received financial compensation. Minimata disease is one of four major pollution diseases of Japan caused by environmental pollution due to improper handling of industrial wastes by Japanese corporations. Compensation, cleanup, and damages cost hundreds of millions of dollars. This episode also served to mobilize international public opinion to the dangers of toxic waste disposal as a health hazard. In 1999, people living in remote areas of Brazil were found to have

methyl mercury poisoning, probably from fish contaminated by methyl mercury used to purify gold.

Toxic Waste Management

Pollution prevention in the workplace has become part of management processes as industry responds to increasing federal and state regulation and as the public demand for greater corporate responsibility leads to increasing punitive litigation. In 1986, the Federal Office of Technology Assessment published a comprehensive work on the topic entitled *Serious Reduction of Hazardous Waste*. A 1992 publication by the OECD called on workers to play a greater role in pollution prevention. The chemical industry responded with the idea of total quality environmental management (TQEM), adopting pollution prevention as

integral to industrial management. Companies such as 3M, Monsanto, and Rhone-Poulenc, and industrial associations (the Chemical Manufacturers' Association) undertook environmental prevention policies. Community activism helped industry to respond positively and openly to environmental hazards in their communities. The search for safe alternatives to toxic chemical waste management can be costly, but inevitably saves a company large expenditures in fines, litigation, and damage to corporate image. The issue is now very broadly shared among government, private industry, workers, and community, involving planners, scientists, engineers, regulators, residents, as well as environmental organizations and consumers.

The EPA is currently promoting waste minimization of persistent, bioaccumulative, and toxic (PBT) chemicals from industrial sources. This includes source reduction by development of new materials for packaging and biodegradable products, recovery of waste electronics, and many other social and public activities for environmental improvement, particularly recycling aimed at reducing hazardous waste products (EPA, 2008). The OECD indicates that the quantity of municipal waste generated in the OECD area exceeded 658 million tonnes in 2010, or 540 kg per inhabitant, a reduction from 2008 despite population growth, possibly related to improvements in waste management and recycling in member countries and to the economic downturn.

In Côte d'Ivoire in August 2006, over 500t of chemical waste was unloaded from a cargo ship and illegally dumped by trucks at several sites. One month later nearly 85,000 consultations were recorded at various medical facilities, with 69 hospital admissions and eight deaths. A mixture of sodium hydroxide, phenols, mercaptanes, hydrogen sulfide, hydrocarbons, and other chemicals used to clean oil transporters' tanks was found in the waste. Serious consequences ensued, as people inundated medical facilities, and many were concerned about damage to the food supply chain and pollution of rivers and lakes. Concern grew since the ship had sailed from northern Europe with calls at a number of other ports, thus making the tracing of sources very difficult.

RADIATION

Radiation occurs when electromagnetic energy travels in waves or subatomic particles through space with a spectrum of varying degrees of energy. The two primary classifications are non-ionizing and ionizing radiation. Non-ionizing radiation indicates radiation in which there is sufficient amount of energy to allow atoms in a molecule to vibrate, but there is not enough to remove electrons. The properties of non-ionizing radiation are used for everyday applications, such as microwaves, radio broadcasting, and infrared heat lamps. Ionizing radiation represents higher

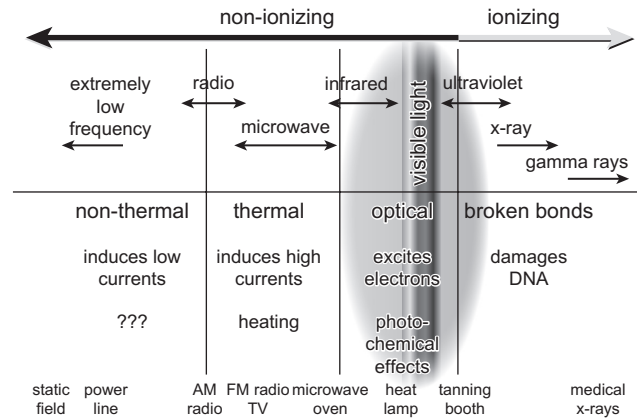


FIGURE 9.5 Spectrum of radiation levels. *Source: Environmental Protection Agency. Radiation: non-ionizing and ionizing [updated 7 August 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/rpdweb00/understand/index.html#nonionizing> [Accessed 17 August 2012].*

levels of energy. Consequently, a charged part of the molecule has the ability to break free from the atom, thus creating particles with a charge, or ions. Ionizing radiation includes particulate radiation of alpha and beta particles, as well as electromagnetic X-rays and gamma rays. Alpha particles are easily stopped by a thin sheet of paper, while beta and gamma radiation can penetrate barriers both inside and outside the body. Ionizing radiation can dislodge atoms or parts of atoms and destroy chemical bonds. This can adversely affect living organisms, especially vulnerable fetal cells, resulting in mutations or carcinogenesis.

Figure 9.5 illustrates radiation energy levels on a spectrum. The degree of energy increases from left to right, non-ionizing radiation to ionizing, as frequency also increases.

Ionizing Radiation

The US National Cancer Institute defines ionizing radiation as follows: "Ionizing radiation is a type of radiation made or given off by x-ray procedures, radioactive substances, rays that enter the Earth's atmosphere from outer space, and other sources. At high doses, ionizing radiation increases chemical activity inside cells and can lead to health risks, including cancer."

Ionizing radiation is characterized by having enough energy to be able pull away tightly attached electrons from their atoms. It includes high-energy electromagnetic radiation, such as X-rays and gamma rays, which are of shorter wavelength and higher energy than UV or visible radiation. It also includes high-energy particles such as electrons, neutrons, protons, and alpha particles. Excessive exposure to these forms of radiation has early and late effects depending on dose and the tissue exposed. Early effects of exposure to high doses of radiation may be fatal owing to acute damage to the gastrointestinal,

erythropoietic (blood-forming), and central nervous systems. Late effects include malignant disease such as leukemia and birth defects.

Background radiation is composed of both natural and artificial sources of radiation. Approximately 81 percent comes from nature, while the remaining 19 percent can be attributed to non-natural sources. The principal sources of radiation exposure for the general public can be broken down as follows: radon (55 percent), external (15 percent), internal (11 percent), medical (15 percent), consumer (3 percent), and other (1 percent). Exposure to ionizing radiation from artificial sources is largely derived from medical procedures. Moreover, natural background radiation is composed of cosmic radiation, terrestrial radiation, and internal radiation. Cosmic radiation is attributed to the sun and stars, which transmit a continuous flow of radiation to Earth. The terrestrial radiation that affects humans comes from the Earth itself, as radioactive substances are naturally present in soil, rock, air, and water. Lastly, humans are exposed to internal radiation, which originates inside the body and is present from birth; people are, in fact, a source of exposure to those around them.

The primary forms of ionizing radiation consist of alpha particles, beta particles, gamma rays, and X-rays. Fairly heavy and high energy, alpha particles have a positive charge. The process of alpha emission can be hazardous to health. This is characterized by a change occurring in the nucleus and a particle being released, resulting in a decay product. The majority of alpha emission takes place naturally in the environment. When soil, minerals, or rock formations are disrupted (such as during mineral extraction), this creates a risk of environmental and human exposure. For instance, high levels of uranium and radium are found in uranium mining wastes. When they rise to the surface, they may contaminate surface water or become airborne. The severity of health effects is highly dependent on the route of exposure. Alpha particles do not have the energy to penetrate the outer skin layer, so exposure external to the body is significantly less harmful than internal exposure. However, if alpha emitters are inhaled or swallowed, or enter the bloodstream, this is a cause for concern. The radiation affects living tissue and may increase the risk of developing cancer, more specifically lung cancer if alpha emitters have been inhaled.

Beta particles have a negative charge, and while their emission can result in serious health problems, their properties are used for various important medical uses. They are important in diagnosis, imaging, and treatment, such as treatment of thyroid disorders and drug metabolism research. Both human-made and naturally occurring beta emitters exist, with some present in our bodies. Health may be compromised when energetic particles are released. Sources of beta particle exposure vary, and may result from a nuclear reactor accident or as a consequence of a

patient taking radioactive iodine. The patient will release beta particles and therefore must adhere to a rigid protocol to prevent exposure to family members. Similar to alpha particles, the route of exposure is important in determining the severity of the health outcome. Inhalation and ingestion are very serious, as particles in contact with living tissue can harm the molecules and disturb cell function. Beta particles are significantly smaller than alpha particles. As a result, they can travel deeper into tissues, causing more widespread cellular damage. In addition, if released from a strong enough source, when beta particles come into contact with skin, they can cause irritation, reddening, or burning. Although radiation from beta particles can result in both acute and chronic health problems, chronic effects are significantly more common. The major health outcome from this radiation is cancer, which typically develops from a relatively low degree of exposure over a long period. It follows a dose-response relationship, in which a higher dose is associated with a higher risk of cancer. While some beta emitters disperse throughout the body, others concentrate in particular organs.

The third class of ionizing radiation is gamma rays. This form of radiation is extremely high energy. Gamma photons are characterized as having no mass and no charge, and being able to travel at the speed of light. They have the power to penetrate many types of objects and materials, including human tissue. As a result, dense, heavy materials are often used as shield to retard or halt gamma photons. Gamma rays and X-rays present similar health risks, their difference lying in the portion of the atom from which they originate. Radionuclides that emit gamma photons are the most commonly used sources of radiation. Some of their uses include treatment of cancer, pasteurization of foods, sterilization of medical tools, and measuring soil density in construction areas. Radioactive isotopes are used in diagnostic examinations, for instance, to obtain images of bone, liver, or brain. For the general population, the majority of gamma exposure comes from natural radionuclides, typically present in soil and water. Further sources include meats and foods that contain high levels of potassium, such as bananas. The majority of gamma and X-ray exposure is external, and the danger lies in the rays' ability to travel far through air and deep into human tissue, putting all organs at risk. For this reason, when X-rays are needed for dental or medical purposes, they are typically carried out in a controlled, well-planned environment. Although less common, radionuclides can release gamma rays that may be ingested with water or food, or inhaled, resulting in internal risks. Determined by the source, the radionuclide can follow different pathways, as it is either absorbed in body tissue or excreted through urine or feces.

Short exposures at high dosage are far more serious than long-term, low-dose exposure. Radiation sickness in people exposed to radiation from the atomic bomb explosions

at Hiroshima and Nagasaki and nuclear accidents ranged in severity, with a variety of short- and long-term responses. The long-term responses have been less severe than originally feared. Ionizing radiation of humans can act as a mutagen, a carcinogen, and a teratogen. It can cause cataracts, impaired fertility, premature aging, and skin damage. Radiation-induced cancer can occur as little as 2–5 years after exposure, or following a latency period of up to 25 years after exposure. Greater risk occurs for those exposed in utero. X-ray-induced disease from excess exposure, faulty equipment, or human error is a hazard of medical care. There is perhaps no safe exposure to ionizing radiation beyond atmospheric background, and any extra exposure should be limited, with prudent exposure to X-rays and limited exposure to atomic radiation from domestic or military uses.

Non-Ionizing Radiation

There are two types of non-ionizing radiation: optic and some electromagnetic fields. Optic radiation includes ultraviolet and infrared. Electromagnetic fields, such as those induced by microwave or radio frequencies, are described in terms of wavelengths or frequency. The harmful effects of non-ionizing radiation are of three main types: photochemical (sunburn or snow blindness), thermal, and electrical.

The health effects of UV radiation include increasing incidence of squamous and basal cell carcinoma and melanoma of the skin, a highly malignant cancer. This kind of radiation is associated with excess exposure to the sun, which in addition to these skin cancers, causes skin and eye burns, cataracts, reduced immunity, and damage to blood vessels. Infrared radiation exposure over long periods is associated with increased risk of cataracts, impaired fertility, and tissue damage. UV radiation is generally classified as non-ionizing radiation; however, in [Figure 9.5](#), it appears to be on the cusp of non-ionizing and ionizing radiation. While most UV radiation is non-ionizing, radiation of higher frequency and higher energy is more powerful, and thus can be considered ionizing.

Long-term exposure to cellular phone use, high-voltage power lines, and radio and radar transmitters is suspected to be associated with increased risk of cancer, but this has not yet been proven. Microwave exposures at high levels can damage vulnerable tissues, but the level of dangerous exposure has not yet been conclusively determined. Lasers are pulsed electromagnetic waves used increasingly in medicine and industry. Excessive use of magnetic resonance imaging (MRI), computed tomography (CT) scans, airport total body scanners and tasers may also contribute to excess radiation exposure, as may the use of cell phones by children as well as adults. Safer technology with reduced radiation should be a high priority as these useful instruments are increasingly used globally.

Low-dose irradiation is used in the production, processing, and handling of foods to prevent food hazards, and is widely supported by professional organizations. It provides an important adjunct to sanitation and good manufacturing practices to reduce morbidity and mortality associated with foodborne diseases, even in industrialized countries. More than 40 years of research and use in the USA and many other countries have demonstrated the effectiveness and safety of low-dose irradiation. This is rapidly becoming an essential part of public health protection from foodborne disease in the USA and internationally, although public acceptance is still problematic.

When discussing different degrees of radiation energy, the issue of both lasers and tasers arises. They are both increasingly used in various fields for a myriad of purposes. Lasers (an acronym for light amplification by stimulated emission of radiation) are used in many electrical devices, and play an important role in law enforcement. They are also used for military, medical, and surgical purposes, skin treatments, hair removal, and in research. Lasers not intended for medical use (and misused medical lasers) can cause irreparable retinal damage and severe burns. The potential for damage to the eye is the principal issue behind laser application, standards, safety, and control measures. The severity of eye damage is determined by both the wavelength and the part of the eye exposed to the laser. If the laser burn affects peripheral vision, this will have minimal or no effect on vision; however, if the fovea is exposed to a laser beam, reading vision may be destroyed.

Tasers are characterized as weapons that function by use of electric currents, which stun and cause temporary debilitation. Those exposed to tasers lose control of their muscles, as the electricity causes involuntary muscle contractions. As these weapons incapacitate normal muscle function, they are widely used by police forces on potentially dangerous individuals to make it easier to arrest or restrain them. According to the US Department of Justice, the use of tasers by law enforcement officials was adopted in an effort to provide stronger control over problematic or aggressive suspects, while resulting in less severe injuries. Despite this, tasers have become very controversial, as there have been cases in which the use of these instruments has resulted in head injuries, broken bones, and even deaths. Because of their potential for misuse and danger, legal restrictions and caution in use are imperative.

ENVIRONMENTAL IMPACT

The US National Environmental Policy Act (NEPA), passed in 1970, made protection and restoration of the environment matters of national policy. NEPA required all federal agencies to take environmental considerations into account in decision-making processes and program implementation. *Environmental impact statements* are required for major construction and public works programs, delineating

positive impact, possible adverse effects, alternatives, and any irreversible effects. This legislation resulted in changes in many national projects and promoted a governmental regulatory approach to supervision, control, and prevention of pollution with materials and processes that could harm human health and the environment.

Emergency Events Involving Hazardous Substances

Since World War II, there has been a rapid increase in the number of chemicals developed and used worldwide. More than 60,000 chemicals are available, with some 600 new substances produced every year, an unknown number of which are hazardous. The health effects resulting from the release of a hazardous substance are often unknown. A hazardous substance release is defined as the uncontrolled or illegal release or threatened release of chemicals or their hazardous byproducts.

Reportable events are defined as those events in which the substances need to be removed or cleaned up. Plant management is liable for damages due to negligence in both civil and criminal law. Where community exposure occurs from negligence, accident, or natural disaster, a public health emergency response is required, based on prior preparation.

The environment is a factor in more than 80 percent of diseases, 23 percent of deaths (premature mortality), 24 percent of the global burden of disease, and more than a third of the burden of disease in children (WHO).

Environmental contaminants such as chemicals and industrial products are responsible for causing approximately 10 percent of all birth defects. There are over 4 million chemicals present in the home and work environments. Some 114 million Americans live in areas where concentrations of air pollution are over the standards, and 41 million live within a 4-mile (6.4km) radius of the 1270 most hazardous sites. In the USA annually, more than 2 billion pounds (1 billion kg) of toxic pollutants are released into the air, and a similar amount into surface water, on to land, or underground. There are at least 10,000 accidental and illegal releases of hazardous chemicals each year, totaling 4.1 billion pounds (1.9 billion kg) of toxic chemicals. Between 2005 and 2013, there were 113,307 hazardous chemical events, with 319 fatalities and a further 11,728 people injured as a result of these incidents (ATSDR, 2013). Volatile organic substances, other inorganic substances, mixtures of more than one chemical, and acids account for more than 51 percent of the hazardous substances released.

European Union (EU) legislation requires member countries to identify high-risk industrial sites, to prevent major accidents, and to limit effects on the population and the environment. The goal is a high level of protection for the population across countries. Even in industrialized

countries, monitoring for heavy metals is problematic. The US Agency for Toxic Substances and Disease Registry (ATSDR) was established by Congress to monitor the effects on public health of hazardous substances in the environment. This includes “public health assessments of waste sites, health consultations concerning specific hazardous substances, health surveillance and registries, response to emergency releases of hazardous substances, applied research in support of public health assessments, information development and dissemination, and education and training concerning hazardous substances” (ATSDR, 2013).

Biomonitoring is a public health standard for assessing human exposure to toxic substances for responding to serious environmental issues. The US national biomonitoring program is based on National Health and Nutrition Examination Surveys (NHANES) of blood, urine, breast milk, and saliva samples to determine population prevalence of toxic chemicals above a known toxicity level (see Chapter 8). The US goal is to increase the number of states and territories that monitor for diseases from heavy metal environmental hazards. Since the publication of the Fourth Report, 2009, tables for 117 chemicals have been updated and 34 chemicals have been added, making a total of 151 chemicals in 2013.

All US states monitor for lead poisoning, while 20 monitor for pesticides, 14 for mercury, 10 for arsenic, 10 for cadmium poisoning, and 35 for birth defects. The goal is to monitor exposure to pesticides in humans by measuring urine concentrations of metabolites. Linked health effect, exposure, and hazard data for environmental public health surveillance were used by 15 states in 2004 (CDC, National Biomonitoring Program, 2013).

Widespread programs for lead exposure reduction and restrictions on lead use have reduced lead exposure in the environment. As a result, lead poisonings have decreased and become less severe, but still occur. CDC estimates that some 500,000 US children aged 1–5 years have blood lead levels (BLLs) greater than 5 micrograms of lead per deciliter of blood ($\mu\text{g}/\text{dl}$), the level at which CDC recommends public health interventions (CDC, Child Lead Poisoning, 2013).

Internationally, a number of major disasters involving radiation has occurred in recent decades (Box 9.25). In Seveso, Italy, in 1976, an explosion in a chemical factory resulted in 17,000 people being evacuated and many terminations of pregnancy among exposed women. An elevated risk of hemopoietic cancers and some elevation of breast cancer risk was found after 20-year follow-up of the exposed population, although no consistent pattern with time since the accident was evident.

In 1984, a sudden release of highly toxic methyl isocyanide from a chemical plant in Bhopal, India, caused thousands of deaths, and blinding and permanent injury of several thousands more, requiring evacuation of an estimated 300,000 people living in adjacent neighborhoods. While

BOX 9.25 Nuclear Accidents: Three Mile Island (1979), Chernobyl (1986), and Fukushima (2011)**Three Mile Island (1979)**

In 1979, the nuclear plant at Three Mile Island in Pennsylvania suffered a near disaster that devastated the plant but did not release nuclear material. It led to a review of safety procedures and heightened public concern as to the overall safety of nuclear energy facilities. There was no loss of life or radiation release, but the incident led to major changes in emergency response planning, operator training, radiation protection, and other safety measures of nuclear power plant operations. It also caused the US Nuclear Regulatory Commission to tighten and heighten its regulatory oversight, resulting in changes in the nuclear power industry and its regulation, with much improved safety.

Chernobyl, Ukraine (1986)

In 1986, a nuclear energy plant located at Chernobyl in the Ukraine (then in the USSR) suffered a meltdown that breached the integrity of the containment vessel, resulting in a massive explosion of the reactor. Design problems and a series of staff errors led to loss of control of the reactor with power levels soaring to 120 times the normal, rupturing the fuel rods, and vaporizing the cooling system. A steam explosion then blasted open the 100-ton concrete slab covering the reactor, starting uncontrollable fires. Despite valiant attempts by emergency personnel and staff, the fires could not be controlled immediately. Air-dropping of sand, lead, clay, and limestone controlled the fire, but the heat of the reactor and radiation could not be reduced for many days. Immediate deaths numbered 33 individuals, mostly among the firefighters, with 237 suffering acute radiation poisoning. Around 135,000 people were evacuated from a 19 square mile (49 km²) area.

The nuclear fallout material carried in a 600-m plume, including iodine-131, cesium-137, and xenon isotopes, spread across much of Europe. Fallout reached some 20 countries, and an international public health threat of major proportions occurred. Ten years after the incident, there was a highly significant increase in thyroid cancer cases in children in the three affected countries: Ukraine, Belarus, and Russia. The long-term effects in terms of increased cancer and birth defects are hard to assess, but current estimates are of 500 (1–2 percent) additional cancer cases among 100,000 people exposed to 10–20 rads. The actual increase in incidence of thyroid cancer, other cancers, and birth defects and the general impact on health will only be determined by careful epidemiological follow-up of the exposed population over many years. The economic impact of the disaster is estimated at over US\$19 billion, and replacement of the plant reaches a similar sum. Close to the tenth anniversary of the Chernobyl disaster, a second nuclear leak nearly occurred due to human error. The Ukrainian government reopened the second reactor in 1999. International assistance in technical and financial aspects of nuclear energy in the Ukraine is in process, but a large area around the plant remains uninhabitable.

Fukushima, Japan (2011)

On 11 March 2011, the Great East Japan Earthquake, with a magnitude of 9.0 on the Richter scale, struck Japan's eastern coast, initiating a string of deadly events. Soon afterwards, the earthquake caused a major, 15-m tsunami tidal wave, which swept the coast of Japan and caused hurricane-scale damage, with many aftershocks. The loss of life was measured in the thousands, with extensive damage to homes, buildings, transportation, and many other community resources. By February 2012, there were 15,534 confirmed deaths and 7092 missing people among 12 prefectures, including Fukushima Prefecture.

The force of the tsunami destroyed the power supply and cooling capabilities of three Fukushima Daiichi reactors, and a nuclear emergency became apparent. The main priority in alleviating the disaster was preventing the reactors from overheating. A second crucial objective was the prevention of radiation leakage, specifically in contaminated water released from the three reactors.

The Fukushima nuclear accident did not cause any deaths or cases of radiation illness; however, this favorable outcome was only achieved through the rapid evacuation of over 400,000 people from within a specified evacuation zone. Despite no fatalities from the nuclear accident, a more tragic outcome shadowed both the earthquake and the tsunami. Owing to the amount of radioactive material released into the air, sea, and land, the Fukushima nuclear accident, caused by the earthquake and tsunami, is considered to be one of the most devastating nuclear accidents globally. Declared a public health emergency requiring worldwide support, the disaster was given the highest rating, level 7, on the International Nuclear Event Scale.

One month after the earthquake, leakage of radioactive material from the power plant remained substantial, and the reactors' inadequate cooling capabilities still posed a serious threat. Cooling operations such as water injection and high-level water spraying were carried out by fire trucks and helicopters. Policies were established, issuing levels of radiation exposure in Japan's ports and in various areas. An area occupying a 20-km radius surrounding the Fukushima Daiichi power plant was pronounced a "No-Entry Zone", and the area is left uninhabited.

Sources: World Nuclear Association. *Chernobyl accident 1986* [updated April 2012]. London: WNA. Available at: <http://www.world-nuclear.org/info/chernobyl/inf07.html> [Accessed 15 August 2012].

Washington State Department of Health. *Background radiation: natural vs. man-made*. Olympia, WA: Washington State Department of Health, Division of Environmental Health Office of Radiation Protection; 2002. Available at: http://www.doh.wa.gov/Portals/1/Documents/Pubs/320-063_bkvsman_is.pdf [Accessed 15 August 2012].

World Nuclear Association. *Fukushima accident 2011* [updated 3 August 2012]. London: WNA. Available at: http://www.world-nuclear.org/info/fukushima_accident_inf129.html [Accessed 17 August 2012].

World Health Organization, Western Pacific Region. *The Great East Japan Earthquake*. Geneva: WHO; 2011. Available at: <http://www.wpro.who.int/publications/9789290615682/en/index.html> [Accessed 17 August 2012].

BOX 9.26 The Bhopal Gas Disaster, 1984

In Bhopal, India, a city of some 900,000 people, an accidental release of methyl isocyanate (MIC) gas from the Union Carbide pesticide plant occurred on the night of 3 December 1984. The gas spread rapidly across the sleeping city. Some 3800 people died within minutes and many others were left with lifelong illnesses.

Failure of inadequate safety systems allowed an estimated 27 tons of MIC gas to escape. A warning siren was turned on, but quickly turned off again so as to not cause panic; however, choking and coughing panic led to chaos and deaths by trampling.

Estimates of the death toll vary; at least 3700 people died from immediate exposure to the gas, with other estimates of up to 8000. In the two decades following the disaster, an estimated 20,000 additional people died from effects of the gas. Estimates of long-term illness vary, with some 120,000 people living with the effects from the gas, including blindness, extreme shortness of breath, cancers, birth deformities, and early onset of menopause. Chemicals from the pesticide plant and from the leak have infiltrated the water system and the soil near the old factory and thus continue to cause poisoning in the people who live near it.

Three days after the disaster, the chairman of Union Carbide, Warren Anderson, was arrested. Released on bail, he fled the country. He is still wanted in India for culpable homicide, but is apparently living in the USA.

Extradition procedures have been obstructed by political issues. Union Carbide claims that the incident was due to

sabotage, but acknowledged responsibility and paid a modest compensation sum of US\$470 million to the families of those who died, although refusing to pay for the long-term effects. The case is still before the courts in India. Regulation of chemical industries remains weak. The Bhopal gas tragedy is remembered as "one of the ugliest industrial disasters that have ever taken place" (Broughton, 2005).

Environmental cleanup has been hampered by a lack of governmental regulatory capacity. In June 2010, seven former employees of the Union Carbide subsidiary, all Indian nationals and many in their seventies, were convicted of causing death by negligence and each sentenced to 2 years' imprisonment and fined. All were released on bail shortly after the verdict. Damages for personal injury, medical monitoring, and injunctive relief in the form of cleanup of the drinking water supplies for residential areas near the Bhopal plant are being sought in an appeal before the federal district court in New York. The legal and political implications of this disaster are still ongoing.

Sources: Sharma DC. *Bhopal's health disaster continues to unfold*. *Lancet* 2002;360:859.

Broughton E. *The Bhopal disaster and its aftermath: a review*. *Environ Health* 2005;4:6. Available at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1142333/> [Accessed 16 July 2013].

Maps of India. *Bhopal gas tragedy* [updated 23 July 2012]. Available at: <http://www.mapsofindia.com/bhopal/gas-tragedy.html> [Accessed 16 August 2012].

About.com. *Twentieth century history. 1984 – Huge poison gas leak in Bhopal, India*. Available at: <http://history1900s.about.com/od/1980s/qt/bhopal.htm> [Accessed 20 August 2012].

the transfer of hazardous occupations and industries to less developed areas is a growing issue, the tragedy at Bhopal led to greater recognition by policy makers and the public that toxic accidents can potentially happen at any time and in any place, not just in developed countries (Box 9.26).

Nuclear and chemical disasters have become a major element in disaster planning for corporate, investor, and occupational and environmental health agencies, as well as for communities adjacent to chemical production, storage, or transportation. Emergency responses to chemical, radiation, or biological catastrophes involve specialized expertise, based on common principles of prevention, monitoring, and crisis management. These include prior emergency planning, speed, coordination of civil and military resources, skilled professional teams providing information to the public, logistic, medical, and laboratory support, on-site case management and evacuation, investigation of causes, and continuous teamwork among all involved agencies.

Human-Caused Disasters

The *Exxon Valdez*, a large oil tanker that ran aground in Alaska in 1989, spilling large amounts of crude oil in Prince William Sound, served as a precedent case in acknowledging that personal and fiscal responsibility for cleanup and other costs to reduce the environmental damage lies with

the company that owns the ship. Cleanup efforts required enormous amounts of money, and the spill became a *cause célèbre* for the environmental movement. The incident highlighted the importance of monitoring seagoing chemical and fuel vessels. New cleanup techniques have been researched and applied in recent years. In response, the Coalition for Environmentally Responsible Economics (CERES) of investment fund advisors and social advocates established the "CERES principles" demanding environmental monitoring of corporations regarding energy use, public disclosure, damage compensation, sustainable use of natural resources, and environmental representatives on boards and in management of corporations. The EPA monitored air, water, sediment, and wastewater generated from the 2010 BP oil spill in the Gulf of Mexico. The response to this disaster was coordinated with four states and the oil company and the cleanup is still being monitored.

War, Terrorism, and Genocide

The man-made disaster of war has used chemical, biological, and nuclear methods of destruction as well as traditional methods of warfare including economic blockade. War's offspring, terrorism, has used chemical armamentaria and may use biological or even nuclear destruction sooner or later. When disasters occur, lessons can be learned to

improve services for future disasters, be they natural or human-made (see Chapter 7).

Although the Hague Convention of 1899 specifically opposed the use of gas in warfare, poison gas has been used as a weapon against both frontline troops and civilian populations since World War I. This practice continues to this day. Gas warfare was banned by international treaty in 1997 under the Chemical Weapons Convention, which has so far been signed by 188 states. The Organization for the Prohibition of Chemical Weapons (OPCW), located in The Hague, oversees the implementation of the guidelines.

In World War I, gas warfare was used by German forces and in retaliation by the Allied armies, primarily with chlorine, mustard gas, and diphosgene. Other gases were also used, including hydrogen cyanide and cyanogen chloride. Gas is estimated to have killed between 300,000 and 900,000 soldiers, mainly in the Russian army, during the war and affected the health of 1 million others. Nerve gases (e.g., sarin, tabun, soman) were developed by the Germans up to World War II. Poison gas was used with deadly efficiency by the Nazis in the Holocaust, but not in warfare because of fear of retaliation.

In the Vietnam War, the US armed forces used napalm widely and Agent Orange as a mass defoliant, with long-term effects on exposed military personnel and Vietnamese civilians, causing large-scale loss of life and birth defects. Egypt used poison gas in its war in Yemen in the 1960s, and in the 1980s Iraq targeted Kurdish villages, killing thousands of civilians.

During the Gulf War of 1991, the potential use of poison gas in long-range rockets on civilian population targets was narrowly averted. Several years later, thousands of US service personnel reported a variety of neurological symptoms and general fatigue. By 1996, these cases were acknowledged by the Department of Defense as possible long-term sequelae of accidental exposure by troops to toxic agents following destruction of Iraqi chemical weapons, or due to antidotes taken for potential gas warfare exposure (soman). In 1995, a chemical attack with a very dangerous chemical warfare agent (sarin) was carried out by an extremist cult in Japan on subway passengers in Tokyo, resulting in 12 deaths and 3000 injuries, and hundreds of hospitalizations.

In 2013, in a bitter civil war in Syria, a neurotoxin (probably sarin) was launched by rockets on to a suburb of Damascus held by rebel forces, killing hundreds of men, women, and children. This gas warfare, suspected to have been carried out by the Syrian regime against civilians of their own country, has provoked international outrage. The issue of chemical, biological, and atomic weapons will reverberate in the Middle East for years to come and may provide precedents for the use of nuclear and biological weapons directed at civilian populations.

Terrorist bombing incidents occurred in many parts of the world during the 1990s. The Lockerbie airplane bombing incident of a Pan Am flight to New York City killed 270 people in 1988. The 1995 bomb detonated by domestic terrorists in a federal building in Oklahoma City in the USA killed

over 160 people. Terrorist bombings of a US military housing complex in Saudi Arabia in 1996, US embassies in Africa in 1998, Moscow apartment buildings in 1999, and Israeli public bus lines and restaurants by suicide bombers killed some 1,000 persons during the second Intifada (2000-2005), and numerous highly lethal suicide bombings in Iraq, Yemen and over 120,000 killed in a civil war in Syria from 2010 to 2013 as well as many terrorist incidents in other parts of the world, caused large numbers of deaths and injuries. Each incident resulted in national concern over the threat of terrorist action causing mass casualties. Destruction of pipelines and oil fields caused extensive environmental damage in the aftermath of the Gulf War in 2001. The infamous September 11, 2001 terrorist attacks in New York City and Washington, DC killed thousands of people and caused many more casualties. They created a new world struggle against terrorism and many major man-made catastrophes. This terrorist event resulted in an unspeakable amount of irreparable damage. Refer to Chapter 10 for a more detailed account of this day and the ensuing health outcomes of this as well as other major disasters.

Unmarked landmines cause huge loss of life and limbs, often among farmers and children. Millions of landmines are present in many areas of conflict, and cleanup is dangerous and costly. Between 2003 and 2005, there were an estimated 7000 landmine deaths and casualties a year worldwide. Most were concentrated in Iraq, Afghanistan, Cambodia, and Colombia. Landmines limit land and water use and have serious economic consequences for farmers. An international movement to ban the use of landmines gained international prominence with support from Princess Diana and by the awarding of the 1997 Nobel Peace Prize to Jody Williams, founder of this movement. Prevention is achieved by raising awareness and political action to prevent landmine use and support efforts for landmine clearance.

The potential for intentional, negligent, or accidental disasters, whether caused by humans or natural, is a real and present danger requiring health officials to coordinate with civil defense and military authorities to prepare disaster plans for such events. Planning can greatly reduce the number and severity of casualties of toxic chemical disasters.

Incitement to organized mass murder of ethnic or political groups has continued into the twenty-first century and constitutes a grave danger to public health as well as to peace. The Syrian crisis of 2011–2013 is a good example of massive use of heavily armed forces against civil uprisings with religious and ethnic overtones and the potential for use of poison gas by the government against the rebel population.

Preventing and Managing Environmental Emergencies

Public health has an important role to play in prevention, management, and mitigation of the effects of human-caused and natural disasters. The US Congress passed the Emergency Planning and Community-Right-to-Know

Act (EPCRA) of 1986 following the 1984 Bhopal disaster (Box 9.26). This legislation established state and local agencies for managing chemical emergencies. It requires facilities that handle hazardous chemicals to make information available to the public and preparedness for possible chemical accidents. This involves a holistic approach integrating technology, procedures, and management practices. The first responsibility lies with management, which must have a high level of awareness and commitment to accident prevention and safe practices. The range of industries at risk is very broad in modern societies; it includes local dry cleaners and furniture manufacturers as well as the chemical industry. The right to know extends from governments, professional societies, trade associations, labor unions, the research community, the news media, and environmentalists as well as the general public. The right to know has become the need to know. Box 9.27 discusses the International Health Regulations and the importance of strong national frameworks capable of managing public health events and situations in which global health is threatened.

Environmental emergencies occur from release of chemicals or radiation into the air. Inhalation and fallout effects downwind of the site depend on weather conditions and dispersal of the smoke plume. Clinical management of exposed civilians and emergency personnel is an activity of health management that involves organizing triage and transportation services at the site of the disaster. The decision to evacuate civilians is often made with limited information but must take into account the potential for exposure during evacuation, weighed against the protective effect of sealing homes and staying indoors (Box 9.28).

The approach to management of environmental health problems requires a continuum of interrelated activities and phases ranging from prevention, through preparedness, detection, and response, to recovery. It includes measures to rebuild infrastructure and also lives and livelihoods affected by the emergency. Prevention is ultimately the most cost-effective and cost-beneficial means of dealing with potential environmental health problems. The principles of disaster and environmental preparedness include:

- planning
- coordination with sister agencies
- preparation
- research
- adaptation with science and technology
- training
- monitoring
- supply
- detection
- prevention
- event
- response
- revision based on lessons learned.

BOX 9.27 Progress of International Health Regulations National Core Capacities

Adopted at the 58th World Health Assembly in 2005, the International Health Regulations (IHR) are an important tool in managing the growing globalized nature of disease transmission and health challenges. Implemented in most countries by June 2007, the IHR are a public health global framework, for consistency in national and international public health programs.

The revised 2005 IHR, a legally binding agreement, includes chemical threats to public health, requiring countries to strengthen capacities on the effects of chemical events on human health. In 2012, a significant 5-year milestone was reached in global efforts to promote national capacities to investigate, evaluate, and take action towards public health events. This requires strategies to create, strengthen, and sustain routine and emergency public health capabilities at identifiable points of entry.

Chemical safety, including prevention and preparedness globally, is promoted through the Strategic Approach for International Chemicals Management (SAICM). The comprehensive approach and global action plan sets out the scope, principles, objectives, financial aspects, implementation, and review arrangements.

The World Health Organization *Manual for Public Health Management of Chemical Incidents* provides a comprehensive overview of the public health management of chemical incidents and emergencies, and outlines the steps to support implementation, with an emphasis on prevention. These include national legislation, policy, and financing; coordination and national focal point (NFP) communications; surveillance; response; preparedness; risk communication; and human resources and laboratory capacity.

Public health has an essential role to play in preventing and minimizing adverse effects of chemical on humans and the environment. With the complexity of environmental challenges, fragmentation of roles and unclear responsibilities are common among the many functional centers, not only across but also within sectors.

Sources: Hardiman MC. World Health Organization perspective on implementation of International Health Regulations. *Emerg Infect Dis* 2012;18(7). Available at: http://wwwnc.cdc.gov/eid/article/18/7/12-0395_article.htm [Accessed 29 June 2012].

World Health Organization. Inter-Organization Programme for the Sound Management of Chemicals (IOMC). Available at: <http://www.who.int/iomc/en/index.html> [Accessed 6 July 2013].

World Health Organization. WHO manual for the public health management of chemical incidents. Geneva: WHO; 2009. Available at: http://whqlibdoc.who.int/publications/2009/9789241598149_eng.pdf [Accessed 6 July 2013].

The appropriate team to handle such a situation involves public health, occupational health, and epidemiology investigators as well as police, fire services, civil defense, armed forces, chemical warfare units, and psychological staff. While it is crucial that experts from a wide range of disciplines are involved in rescue and relief efforts, it must be recognized how to apply the most effective model of management. The

BOX 9.28 Emergency Procedures for Hazardous Substances, Chemical, or Radiation Disasters

- Plan and prepare local public health, hospital, and other first responders for possible chemical or radiation disasters or attacks.
- Establish early warning reporting and communication procedures.
- Contain and reduce spread of the toxin.
- Inform the community to remain inside homes or other buildings.
- Notify municipal, state, and federal emergency organizations.
- Minimize exposure by ensuring the potentially exposed population remains inside, with the affected areas sealed off and quarantined or by limited evacuation.
- Identify, decontaminate, and triage exposed persons.
- Measure exposure and reaction.
- Determine causative agents and antidotes.
- Initiate antichemical procedures for exposed persons including removal of clothing, showers, and antidote.
- Coordinate on-site triage and evacuation for medical care.
- Ensure medical or hospital care for exposed persons.
- Provide accurate information to the public.
- Promote health and supportive care at evacuation sites.
- Investigate – professional and criminal.
- Compensate the injured or displaced.
- Pursue civil and criminal charges against negligent management persons and corporations.
- Provide documentation and recommendations from lessons learned.
- Review procedures and revise disaster plan operation.
- Promote public and professional discussion.

Sources: Khan AS, Levitt AM, Sage MJ. *Biological and chemical terrorism: strategic plan for preparedness and response: recommendations of the CDC Strategic Planning Workgroup*. *MMWR Recomm Rep* 2000;49:1–14. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/rr4904a1.htm> [Accessed 17 August 2012].

Environmental Protection Agency. Emergency management [updated 3 August 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/emergencies/index.htm> [Accessed 15 August 2012].

most desirable outcomes (lowest possible rates of deaths, injuries and least amount of damage) will result from use of a chain-of-command system. Past public health emergencies, such as Hurricane Katrina and the BP oil spill off the Gulf of Mexico, illustrate system weaknesses and inadequate management of personnel and responsibilities. Many experts agree that effective management will only occur once society chooses to adopt a military approach of command, with a single chain of authority and accountability.

Moreover, relief efforts do not end once the surroundings of a public health disaster have been cleaned up; post-disaster recovery planning is part of the planning process. (Disaster planning is discussed in Chapter 7.) Long-term effects include post-traumatic stress disorder (PTSD), which can result in serious psychological dysfunction in

affected individuals. PTSD can be alleviated by early psychological support for victims of mass disasters at the site and at evacuation or follow-up centers, and should be part of emergency care planning.

Rapid risk assessment involves weighing the hazard, exposure potential, dose–response, and both short- and long-term risks. Command centers and designated leaders are needed to maintain control of the multitude of needs for information, coordination between agencies, and the distribution of resources to areas of greatest need. Long-term epidemiological assessment may be necessary for legal and compensation purposes, as well as for training and preparation for future events.

Advocacy is a key public health function, and environmental and safety issues are areas where advocacy can bring important public benefit. Leadership in defining public health problems and in defining necessary action to reduce risk factors, or short- or long-term ill-effects, requires skill in interpretation of epidemiological events and studies, providing perspective for policy makers addressing those issues.

ENVIRONMENTAL HEALTH ORGANIZATION

The World Health Organization Commission on Health and Environment Report (1992) developed a consensus documentation of international environmental health issues. This commission, chaired by Simone Weil of the European Parliament, included many distinguished scientists, professional leaders, and international organizations. The report represented a strong international consensus on joint action to prevent and clean up environmental degradation that had occurred in Europe over several decades.

National organization for environmental health can take various forms. In the past, it was common for ministries of health to have environmental health departments, but in recent years this has increasingly moved to ministries of the environment.

Since 9/11, there has been increased governmental and public concern regarding possible emergencies along with environmental decay and incidents of food or waterborne disease. The possibilities of natural and human-made disasters in the environment call for renewed efforts to prepare emergency plans, and conduct suitable training and exercises with public health, hospital, and primary care centers, as well as ambulance, fire, police, and military services.

Terrorist incidents may involve microbiological (bacterial, viral) pathogens, nerve gas (e.g., sarin), and lethal plant toxins (e.g., ricin), as well as explosive or firearm attacks. Preparing “homemade” agents or explosive devices can be technically simple. Weaponization of biological agents for localized or mass dissemination is feasible and such agents have been used. Many potential biological agents prepared in military or secret warfare laboratories could possibly reach terrorist groups. Such agents may be

highly contagious, causing public panic and high mortality rates. Public health and other local first responders including police, fire services, emergency evacuation ambulance, medical and hospital providers, volunteers and social services may all be required in rapid mobilization. Large-scale attacks with chemical or microbiological agents require rapid procurement and distribution of large quantities of drugs and vaccines, which must be available quickly.

Natural and other environmental disasters require at least as much mobilization as local terrorist acts, and may cause damage on a massive scale due to droughts, floods, hurricane, tsunamis, oil spills, and forest fires, all of which happen on a frequent basis in many especially vulnerable parts of the world. The challenges include massive evacuation, damage control, security, provision of food, water and shelter, prevention of epidemic disease, reconstruction, and rehabilitation of refugees (see Chapter 10 and <http://www.epa.gov/emergencies/index.htm>).

Because of concern over environmental decay and fragmentation of government regulation efforts, the EPA was established in the USA in 1970 as the head federal agency reporting to the president to coordinate the administration of a wide range of environmental health problems. The EPA sets standards and regulations for a variety of legislation pertaining to the environment, such as air and water pollution, solid and hazardous waste management, noise, public water supplies, pesticides, and radiation. Despite the growth of the EPA and its control of a superfund to reduce toxic and other waste sites, interagency coordination is complex. In the US federal government, a wide variety of agencies located in different government departments has responsibilities related to the environment (Box 9.29). The substantial environmental progress made in the USA in the past 25 years is outlined in Table 9.4.

BOX 9.29 US Federal Government Agencies with Environmental Responsibilities

- Environmental Protection Agency (Independent)
- Council on Environmental Quality (Executive Office)
- Nuclear Regulatory Commission (Independent)
- Office of Environmental Safety and Health (Department of Energy)
- Office of Environmental Management (Department of Energy)
- Office of Environmental Policy and Assistance (Department of Energy)
- Office of Surface Mining Reclamation and Enforcement (Department of the Interior)
- Bureau of Land Management (Department of the Interior)
- Center for Environmental Health, CDC (Department of Health and Human Services)
- National Institute of Occupational Safety and Health (NIOSH) (CDC)
- Consumer Product Safety Commission (Independent)
- Public Health Service (Department of Health and Human Services)
- Centers for Disease Control and Prevention (Department of Health and Human Services)
- Food and Drug Administration (Department of Health and Human Services)
- Agency for Toxic Substances and Disease Registry (Department of Health and Human Services)
- Occupational Safety and Health Administration (OSHA) (Department of Labor)
- Mine Safety and Health (Department of Mines)
- Fish and Wildlife Service (Department of the Interior)
- Soil Conservation Service (Department of Agriculture)
- Department of Homeland Security

Note: The department under which each agency falls is listed in parentheses.

TABLE 9.4 Environmental Milestones in the USA, 1970–2006

1970	President Richard Nixon creates EPA to protect the environment and public health. Congress amends the Clean Air Act to set national air quality, auto emission, and antipollution standards
1971	Congress restricts use of lead-based paint in residences and on cribs and toys
1972	EPA bans DDT, a cancer-causing pesticide, and requires extensive review of all pesticides USA and Canada agree to clean up the Great Lakes, which contain 95 percent of America's freshwater Congress passes the Clean Water Act, limiting raw sewage and other pollutants flowing into rivers, lakes, and streams Only 36 percent of the nation's assessed stream miles are safe for fishing and swimming; in 2006 about 60 percent are safe for such uses
1973	EPA begins phasing out leaded gasoline; OPEC oil embargo triggers energy crisis, stimulating conservation and research on alternative energy sources. EPA issues its first permit limiting a factory's polluted discharges into waterways. Endangered Species Preservation Act passed
1975	Congress establishes fuel economy standards and sets tailpipe emission standards for cars, resulting in the introduction of catalytic converters
1976	Congress passes the Resource Conservation and Recovery Act, regulating hazardous waste from its production to its disposal President Gerald Ford signs the Toxic Substances Control Act to reduce environmental and human health risks; EPA begins phase-out of cancer-causing PCB production and use
1977	Clean Air Act Amendments to strengthen air quality standards and protect human health

TABLE 9.4 Environmental Milestones in the USA, 1970–2006—cont'd

1978	Residents discover Love Canal, New York, is contaminated by buried leaking chemical containers Federal government bans CFCs as propellants in aerosol cans; CFCs destroy the ozone layer which protects the Earth from harmful ultraviolet radiation
1979	EPA demonstrates scrubber technology for removing air pollution from coal-fired power plants. This technology is widely adopted in the 1980s Three Mile Island nuclear power plant accident near Harrisburg, Pennsylvania, increases awareness and discussion about nuclear power safety. EPA and other agencies monitor radioactive fallout
1980	Congress creates a superfund to clean up hazardous waste sites. Polluters are made responsible for cleaning up the most hazardous sites. Agency for Toxic Substances and Disease Registry created
1981	National Research Council report finds acid rain intensifying in the north-eastern USA and Canada
1982	Nuclear Waste Repository act for safe disposal of nuclear waste Dioxin contamination forces the government to purchase homes in Times Beach, Missouri; federal government and responsible polluters share the cleanup costs A PCB landfill protest in North Carolina begins the environmental justice movement
1983	Cleanup actions begin to rid the Chesapeake Bay of pollution stemming from sewage treatment plants, urban runoff, and farm waste EPA encourages homeowners to test for radon gas, which causes lung cancer; more than 18 million homes tested for radon. Approximately 575 lives are saved annually due to radon mitigation and radon-resistant new construction
1984	Bhopal disaster in India stirs public opinion on chemical industrial hazards globally
1985	Scientists report that a giant hole in the Earth's ozone layer opens each spring over Antarctica
1986	Congress declares the public has a right to know when toxic chemicals are released into air, land, and water. Superfund Amendment Act promotes hazardous site cleanup
1987	USA signs the Montreal Protocol, pledging to phase out production of CFCs Medical and other waste washes up on shores; beaches closed in New York and New Jersey
1988	Congress bans ocean dumping of sewage sludge and industrial waste
1989	Exxon Valdez spills 11 million gallons of crude oil in Alaska's Prince William Sound
1990	Clean Air Act Amendments require states to show progress in improving air quality EPA Toxic Release Inventory of pollutants released from specific facilities in their communities Number of chemicals listed in EPA's Toxic Release Inventory nearly doubled, from 328 in 1990 to 644 in 1999 Pollution Prevention Act signed, emphasizing importance of preventing, not just correcting, environmental damage National Environmental Education Act signed, for educating the public to ensure scientifically sound, balanced, and responsible decisions about the environment
1991	Federal agencies begin using recycled content products. EPA launches voluntary industry partnership programs for energy-efficient lighting and for reducing toxic chemical emissions
1992	EPA launches the Energy Star® Program to help consumers identify energy-efficient products
1993	EPA reports that secondhand smoke contaminates indoor air, with serious health risks to non-smokers <i>Cryptosporidium</i> outbreak in drinking water in Milwaukee, Wisconsin, sickens 400,000 people and kills more than 100 Federal government uses its US\$200 billion annual purchasing power to buy recycled and environmentally preferable products
1994	EPA Brownfields Program to clean up abandoned, contaminated sites to return them to productive community use EPA issues new standards for chemical plants to reduce toxic air pollution by more than half a million tons each year, equivalent to removing 38 million vehicles annually
1995	EPA launches an incentive-based acid rain program to reduce SO ₂ emissions EPA requires municipal incinerators to reduce toxic emissions by 90 percent from 1990 levels
1996	Public drinking water suppliers required to inform customers about chemicals and microbes in their water; funding made available to upgrade water treatment plants Vast majority of American households now have safe drinking water EPA requires that home buyers and renters be informed about lead-based paint hazards Food Quality Protection Act signed to tighten standards for pesticides used to grow food, with special protections to ensure that foods are safe for children to eat
1997	Executive Order issued to protect children from environmental health risks, including childhood asthma and lead poisoning EPA issues tough new air quality standards for smog and soot, an action that would improve air quality for 125 million Americans Chemical Weapons Convention banning chemical warfare, now signed by 188 nations
1998	Clean Water Action Plan announced to continue making America's waterways safe for fishing and swimming

Continued

TABLE 9.4 Environmental Milestones in the USA, 1970–2006—cont'd

1999	New emissions standards for cars, sport utility vehicles, minivans and trucks, requiring them to be 77–95 percent cleaner in the future EPA announces new requirements to improve air quality in national parks and wilderness areas
2000	EPA establishes regulations requiring more than 90% cleaner heavy-duty highway diesel engines and fuel
2002	Small Business Liability Relief and Brownfields Revitalization Act signed to reclaim and restore thousands of abandoned properties
2003	Healthy Forests Restoration Act signed to prevent forest fires and preserve nation's forests Over 4000 school buses to be retrofitted through the Clean School Bus USA program, removing 200,000 pounds of particulate matter from the air over next decade Clear Skies legislation and alternative regulations proposed to create a cap and trade system to reduce SO ₂ emissions by 90 percent and NO _x emissions by 65 percent below current levels
2004	New, more protective, 8-hour ozone and fine particulate standards go into effect across the country. Clean Air Rules of 2004 are proposed that will make people healthier EPA requires cleaner fuels and engines for off-road diesel machinery such as farm or construction equipment
2005	EPA issues the Clean Air Interstate Rule and the Clean Air Mercury Rule
2006	Program to raise awareness about the importance of water efficiency and water-efficient products, and provide good consumer information. Clean Water Restoration Act of 2007 to clarify federal jurisdiction in surface waters in process in Congress
2010	California Desert Protection Act for conservation areas
2012	EPA issues new emission standards for industrial sites

Note: EPA = Environmental Protection Agency; DDT = dichlorodiphenyltrichloroethane; OPEC = Organization of the Petroleum Exporting Countries; PCB = polychlorinated biphenyl; CFC = chlorofluorocarbon; SO₂ = sulfur dioxide; NO_x = nitrogen oxides.

Sources: Environmental Protection Agency. Earth day and EPA history [updated 12 July 2011]. Washington, DC: EPA. Available at: <http://www.epa.gov/earthday/history.htm> [Accessed 15 August 2012].

Environmental Protection Agency. Water sense [updated 20 July 2012]. Washington, DC: EPA. Available at: <http://www.epa.gov/watersense/> [Accessed 16 August 2012].

OCCUPATIONAL HEALTH

INTRODUCTION

One of the main functions of the WHO was mandated in Article 2 of its 1946 Constitution: to promote improvement of working conditions and other aspects of environmental hygiene. This mandate led to international recognition that occupational health is closely linked to public health and health systems development. All determinants of workers' health, including risks for disease and injury in the occupational environment, social and individual factors, and access to health services, need to be addressed.

The CDC considers the improvement in workers' health and safety as one of the 10 great achievements of public health in the USA in the twentieth century. The US National Safety Council reports from 1933 to 1997 indicate that deaths from unintentional work-related injuries declined by 90 percent, from 37 per 100,000 workers to 4 per 100,000, a "reduction of the number of deaths from 14,500 to 5,100; during this same period, the workforce more than tripled, from 39 million to approximately 130 million" (CDC, 1999).

Occupational health is the promotion and maintenance of the highest levels of physical, mental, and social

well-being of workers in all occupations by preventing departures from health, controlling risks, and adapting of work to people and people to their jobs (International Labour Organization and WHO, 1950). Diseases related to occupations, always an essential part of public health, increasingly relate to environmental health, but to other fields as well. The worker is also a member of a family and a breadwinner, so the health of the worker is related to family health. The worker is concerned not only with what happens at the place of employment but also with hazardous agents that he or she might accidentally bring home. The retired or laid-off worker is worried about well-pensioned and honorable retirement. Occupational health in this wider context has an important place in the New Public Health.

DEVELOPMENT OF OCCUPATIONAL HEALTH

Occupational health is one of the oldest sectors of public health, dating back to Roman times. Documentation of occupational diseases began in 1700 by Bernardino Ramazzini (1633–1714) (see Chapter 1). Historic examples of work-related health hazards and diseases include scurvy among sailors, cancer of the scrotum specific to chimney

sweeps in nineteenth-century England, black lung in coal miners, mercury poisoning in hat makers, byssinosis in cotton mill workers, and mesothelioma in asbestos workers. The list is long and extends to musculoskeletal injuries and hepatitis B in hospital workers, spinal disorders in typists, and medial neuritis (carpal tunnel syndrome) in computer users. Interventions vary widely, from the banning of asbestos use to modifying the office work environment through better chairs, exercise breaks, and ergonomic training of workers.

During the early part of the nineteenth century, the harsh working conditions of children, women, and other workers led to parliamentary action to regulate mines and factories, improving conditions generally. The first factory inspectors in the UK were appointed in 1833 to administer the provisions of the Factory and Workshops Acts. In 1898, Thomas Legge became the first medical doctor appointed to the post of Chief Factory Inspector in the UK. He articulated the basic public health approach to workers' health and established the principle that management is responsible for the health of the employees. These issues are termed Legge's axioms and are still relevant to the field of occupational health today (Table 9.5).

Government responsibility for setting standards, monitoring, intervening, and regulating compensation grew slowly over the past century. Case reports, epidemiological studies, and advocacy regarding the effects of lead, asbestos, vinyl chloride, silica, and dust fibers led to steps to reduce the hazards to workers and provided the professional support for legislative initiatives. International standards developed by the League of Nations, the International Labour Organization, and other international organizations promoted development of this field.

THE HEALTH OF WORKERS

Workers are subject to normal health threats for the adult population, but there are specific threats to health associated with the work situation. Workers have lower death rates than the general population because they are demographically different from the general population and even epidemiologically different from a population matched for age and gender. This is due to the fact that there is a process of selection of workers that excludes the severely ill and disabled from employment. The selection process continues with attrition of unhealthy people from the workplace. This is termed the *healthy worker effect* and is a factor that needs to be considered in occupational health studies and practice. Death rates or other population-based norms from the general population may be inappropriate for comparison if this effect is not taken into account. Case matching or control studies may be needed to accommodate this phenomenon. Other population groups such as immigrants or refugees go

through similar selection, where only the healthy may be included or survive.

THE BURDEN OF OCCUPATIONAL MORBIDITY AND MORTALITY

In the USA, the workforce is made up of 154 million people, with 66.9 percent between the ages of 25 and 54. The age group 25–54 years is projected to decline to 63.7 percent of the total population in 2020. Workforce participation declined during the 2007–2009 recession by 2.4 percent and is projected to decline further by 2.2 percent by 2020.

Premature disease, injury, and death related to occupational exposures are a major burden on the economy and the health system. The number of fatal and non-fatal injuries in the USA in 2007 was estimated to be more than 5600 and almost 8,559,000, respectively, at a cost of US\$6 billion and US\$186 billion. The number of fatal and non-fatal illnesses was estimated at more than 53,000 and nearly 427,000, respectively, with cost estimates of US\$46 billion and US\$12 billion. National costs of occupational injury and illness among civilians in the USA for 2007 were estimated at US\$67 billion, and indirect costs were almost US\$183 billion, equivalent to the costs of cancer (Leigh, 2011).

The largest numbers of deaths occur in the following industries: construction, transportation/communications/public utilities, and manufacturing (14.0 percent). The decrease in occupation-related deaths from 1980 to 2005 is related to the cumulative effect of increased awareness and regulation of worksite dangers and toxins, as well as new technology and mechanization, changes in the economy, and workforce distributions (CDC MMWR, 1999).

In 2001 in the USA, there were 5.7 non-fatal injuries with lost workdays per 100 employees in the private sector, a reduction of 34 percent from 1992. There was a trend towards substantial improvements in the more dangerous occupations such as agriculture, fishing and forestry, mining, construction, and manufacturing during the 1990s and early twenty-first century, as seen in Table 9.6.

The 10 most frequent work-related diseases and injuries in the USA are:

- lung disease
- musculoskeletal injuries
- cancers
- severe trauma
- cardiovascular disorders
- disorders of reproduction
- neurotoxic disorders
- noise-related hearing loss
- dermatological conditions
- psychological strain and boredom.

TABLE 9.5 Thomas Legge's Axioms on Workers' Health and Modern Equivalents

Legge's Axiom	Modern Version
Unless and until the employer has done everything – everything means a good deal – the workman can do next to nothing to protect himself.	Don't blame the victim; the health of workers is the responsibility of management.
If you can bring an influence to bear, external to the worker, that is one over which he can exercise no control, you will be successful; if you cannot or do not, you will never be wholly successful.	Structural change is best.
Practically all industrial lead poisoning is due to inhalation of dust and fumes.	If you stop the exposure, you stop the poisoning.
All workmen should be told something of the danger of the material with which they come into contact and not be left to find out for themselves – sometimes at the cost of their lives.	Workers have the right to their health at their place of employment.

Sources: Harrington JM. 1998 and beyond – Legge's legacy to modern occupational health. *Ann Occup Hyg* 1998;43:1–6. Available at: <http://www.sciencedirect.com/science/article/pii/S0003487898000751> [Accessed 17 August 2012].

Waldron T. Thomas Morison Legge (1863–1932): the first medical factory inspector. *J Med Biogr* 2004;12:202–9. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15486616> [Accessed 18 August 2012].

TABLE 9.6 Occupational Injury Death Rates (per 100,000 Workers) by Industry, USA, Selected Years 1985–2010

Industry	1985	1990	1993	2003	2005	2010	% Change 1985–2010
Total civilian workforce	5.8	4.6	4.2	4.0	4.0	3.5	–39.6
Mining	30.0	30.0	25.4	26.9	25.6	19.8	–34.0
Agriculture, fishing, forestry	23.7	18.0	18.5	31.9	32.5	26.8	+11.6
Construction	16.6	14.0	11.8	11.7	11.1	9.5	–42.7
Transportation, communication, public utilities	15.7	10.4	10.1	17.8	17.7	17.1	+8.9
Public administration	6.4	3.8	4.2	2.7	2.4	2.2	–65.6
Manufacturing	4.0	4.0	3.6	2.5	2.4	2.2	–45.0
Wholesale trade	2.8	3.6	3.6	4.2	4.6	4.8	+74.1
Retail trade	2.7	2.8	2.9	2.1	2.4	2.2	–18.5
Services	1.8	1.5	1.4	NA	NA	NA	–

Sources: National Center for Health Statistics. Health, United States, 2007, with chartbook on trends in the health of Americans. Hyattsville, MD: US Department of Health and Human Services; 2007. Available at: <http://www.cdc.gov/nchs/data/hs/hs07.pdf> [Accessed 17 August 2012].

National Center for Health Statistics. Health, United States, 1998, with socioeconomic status and health chartbook. Hyattsville, MD: US Department of Health and Human Services; 1998. Available at: <http://www.cdc.gov/nchs/data/hs/hs98.pdf> [Accessed 17 August 2012].

Bureau of Labor Statistics. National census of fatal occupational injuries in 2010 (preliminary report). Washington, DC: US Department of Labor; 2011. Available at: <http://www.bls.gov/news.release/cfoi.nr0.htm> [Accessed 17 August 2012].

A preliminary total of 4547 fatal work injuries was recorded in the USA in 2010, about the same as the final count of 4551 fatal work injuries in 2009. The rate of fatal work injury for US workers in 2010 was 3.5 per 100,000 full-time equivalent (FTE) workers (Table 9.6), as was the final rate for 2009 (US Bureau of Labor Statistics, National Census of Fatal Occupational Injuries, 2010).

Occupational Health Priorities in the USA

Priorities for research in occupational health are focusing on work-related anxiety and neurotic disorders, hearing loss, musculoskeletal disorders, injuries (fatal and non-fatal), poisoning, respiratory conditions, and skin disorders.

These are the most common occupational health issues and the costliest to the economy (CDC, Worker Health Chartbook, 2004). Injury surveillance in the USA is maintained by the CDC's National Institute of Occupational Safety and Health.

INTERNATIONAL ISSUES IN OCCUPATIONAL HEALTH

The WHO defines occupational health as including: “all aspects of health and safety in the workplace”, and occupational health “has a strong focus on primary prevention of hazards. The health of the workers has several determinants, including risk factors at the workplace leading to cancers,

BOX 9.30 Occupational Health Issues in the Global Economy

- Technology transfer from industrial to developing countries or areas within a country
- Child labor, sexual exploitation and slave-like conditions in low income countries
- Pesticide overuse, toxicity, and food contamination
- Ecological damage from toxic waste spills and waste disposal
- Toxic waste transfer from industrial to developing countries
- High-technology industrial toxic wastes
- Nuclear energy, accidents, and wastes
- Technological and professional common interest between occupational and environmental health
- Poor safety and control standards in former Soviet and developing countries
- Poor wages, psychological stress, boredom, and shift work
- Management negligence and lack of accountability for workplace safety
- Governmental negligence and corruption in developing regulatory role
- Dangerously inadequate health and safety measures in developing countries, e.g., Bangladesh clothing workers disasters 2013
- Widening income gap between upper and lower income groups

accidents, musculoskeletal diseases, respiratory diseases, hearing loss, circulatory diseases, stress related disorders and communicable diseases and others. Employment and working conditions in the formal or informal economy embrace other important determinants, including, working hours, salary, workplace policies concerning maternity leave, health promotion and protection provisions” (WHO, 2012).

WHO is implementing a Global Plan of Action on Workers’ Health 2008–2017, endorsed by the World Health Assembly in 2007, with the following objectives:

- devising and implementing policy instruments on workers’ health
- protecting and promoting health at the workplace
- improving the performance of and access to occupational health services
- providing and communicating evidence for action and practice
- incorporating workers’ health into other policies.

Occupational health has become an international issue as the global economy enables the transfer of manufacturing from one country to another with great speed and ease (Box 9.30). This is often motivated by lower wages, and also by lower occupational and environmental regulatory controls and less stringent or non-existent legal protection against toxic exposures and child labor in developing

countries. Transfer of occupational hazards from industrialized to non-industrialized countries has become an issue in international cooperation and trade agreements. Developed countries have stricter environmental regulations and worker organization than developing countries that are anxious for job-producing industry at any price.

In 2000, occupational risk factors were responsible worldwide for 37 percent of back pain, 16 percent of hearing loss, 13 percent of chronic obstructive lung disease (COPD), 11 percent of asthma, 8 percent of injuries, 9 percent of lung cancer, and 2 percent of leukemia. These risks at work caused 850,000 deaths worldwide and resulted in the loss of about 24 million years of healthy life. Needle-stick injuries accounted for about 40 percent of hepatitis B and hepatitis C infections and 4.4 percent of HIV infections in health care workers. Exposure to occupational hazards accounts for a significant proportion of the global burden of disease and injury, which could be substantially reduced through application of proven risk prevention strategies.

NATIONAL AND MANAGEMENT RESPONSIBILITIES

In the USA, workers’ health benefits cost more than the steel to make a car. As a result, there is a growing interest on the part of both management and workers in promoting workers’ health through improved nutritional monitoring of canteens and cafeterias, antismoking activities, and physical fitness programs. The management interest in a healthier workforce to contain rising health care costs is part of the modern corporate culture. The primary responsibility, however, legally and morally, lies with management, in addition to protecting the worker by monitoring risks, providing a safe environment, and providing care at the time of injury (Box 9.31).

More than 23 million Americans have asthma and a further 13.6 million have COPD. The workplace environment often results in exposure to many chronic respiratory hazards among workers. Examples of respiratory hazards identified in the past 10 years include butter-flavouring chemicals; minifibers (flock) of nylon, rayon, and polypropylene; and dust from the World Trade Center. Analysis of workplace asthma in the USA showed that among adults an annual average of 1.4 million cases of workplace-related asthma could be prevented (Box 9.32).

Occupational injuries and illnesses are social as well as engineering and management concerns. Compensation, litigation, class-action suits, and union action are all associated with increasing awareness of toxic and trauma effects on workers, and court decisions regarding management liability. The field is made more complex because some occupational illness may occur long after the exposure: silicosis, asbestos-related mesothelioma, and asbestosis may develop after a long latency of up to 20–30 years following exposure.

BOX 9.31 Principal Tasks of Occupational Health

- *Anticipation* – dealing with potential disease and injury to include preparation for prevention as facilities are planned or renovated.
- *Surveillance and monitoring* – assuring timely and accurate identification, reporting, and recording of occupational disease and injury; medical surveillance: passive or active and industrial hygiene and safety.
- *Right to know* – for workers, health professionals, community at large.
- *Epidemiological analysis* – analyzing collected data; linking exposure to outcome data helps to locate trends, clusters, associations, and causes of disease and injury for more in-depth investigation and prevention.
- *Exposure reduction* – minimizing toxic exposure, to prevent approaching or exceeding established limits.
- *Substitution* – substituting less toxic substances.
- *Awareness* – promoting awareness at government, management, community, worker, and consumer levels.
- *Government regulation* – on-site supervision by regulatory agencies; publication of standards of exposure and “good practices”.
- *Compensation* – compensating for illness and loss of life related to work accidents, toxicity, and stress.
- *Management-worker cooperation* – recognizing that worker participation in health and safety is of mutual benefit.

Source: Weeks JL, Levy BS, Wagner GR, editors. *Preventing occupational disease and injury*. Washington, DC: American Public Health Association; 2005.

Follow-up of exposed workers may be difficult, and issues such as compensation may also be complicated. Occupational health involves a governmental regulatory function and legislated responsibility to protect workers from toxic or physical risks at the worksite and those exposed to the workers and the products found in the environment (e.g., asbestos fibers on workers’ clothing). In 2012, preliminary findings were reported of excess cancer rates among people working with asphalt roofing, a reminder of Percivall Pott’s findings of cancer of the scrotum among young chimney sweeps in the late eighteenth century.

Standards and Monitoring

Monitoring of occupational health involves a set of activities designed to increase the safety and protection of the workers. It involves a number of parallel services to promote the health of the individual worker and the safety of the work environment, and should be coordinated in an overall strategy.

In the USA prior to 1970, prevention of occupational injuries, death, and disease was governed by state and local government or market forces. Federal initiatives to raise

BOX 9.32 Work-Related Asthma, USA (38 States and District of Columbia), 2006–2009

The CDC reports that work-related asthma (WRA) includes exacerbation of pre-existing asthma concurrent asthma worsened by factors related to the workplace environment. Occupational asthma is new-onset asthma attributed to the workplace environment. WRA is a preventable occupational lung disease associated with serious adverse health and socioeconomic outcomes.

Among workers with similar occupational exposures, WRA diagnosis offers unique opportunities for prevention. The American Thoracic Society estimated that for 15 percent of US adults with asthma the condition is attributable to occupational factors.

To estimate current asthma prevalence and the proportion of asthma that is WRA, CDC analyzed data from the 2006–2009 Behavioral Risk Factor Surveillance System (BRFSS) from 38 states and the District of Columbia (DC).

Among ever-employed adults with current asthma, the overall proportion of WRA was 9.0 percent, ranging from 4.8 to 14.1 percent in different states. Proportions of WRA were highest among people aged 45–64 years (12.7 percent), blacks (12.5 percent), and people of other races (11.8 percent).

Source: Centers for Disease Control and Prevention. *Work-related asthma – 38 states and District of Columbia, 2006–2009*. *MMWR Morb Mortal Wkly Rep* 2012;61:375–8. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6120a4.htm> [Accessed 17 August 2012].

standards of occupational health and safety were mandated in the Occupational Safety and Health Act of 1970, which established two government agencies to implement the Act, the Occupational Safety and Health Administration (OSHA) and the CDC’s National Institute of Occupational Safety and Health (NIOSH). OSHA is responsible for promulgation and enforcement activities, within the US Department of Labor. OSHA sets standards based on consensus derived from professional organizations in consultation with labor, industry, and health authorities, meant to promote safety and reduce risk for employees and set performance standards for employers. NIOSH was established to conduct research related to the objects of the act for occupational disease, particularly those derived from exposure to toxic physical and chemical agents.

The Act provides an environment for regulation and study of occupational health issues including public petitions, court decisions, and new research findings used to formulate priorities for standards development. Monitoring is done by a combination of federal, state, and local health authorities with participation of professional and industrial organizations. The legal responsibility for worker safety and health is placed with the employer (Table 9.7), but worker awareness and participation in safety programs are vital to a successful approach.

TABLE 9.7 Management and Governmental Responsibilities in Workers' Health

Management Responsibility	Governmental Responsibility
Substitute less dangerous materials	Legislation – substitute, ban, define legal responsibility (civil and criminal compensation)
Enclose/separate dangerous materials	Regulation to set and enforce standards for toxic emissions and controls
Process exhaust fumes	Litigation – civil suits vs. compensation
General ventilation	Test environment and workers with notification of test results
Good housekeeping	Designation of hazardous materials, labeling, disposal and reporting requirements
Monitor health of workers	Monitor health of workers
Personal protection	Educate managers and workers
Investigate potential unhealthy events	Research – scientific and operational
GMP (good manufacturing practices)	Regulate compensation for income loss and health damage
Payment for workers' compensation protection	Compensation for injury or disease

OCCUPATIONAL HEALTH TARGETS

The US Surgeon General's report *Healthy People 2020* formulated a number of targets for occupational health and safety issues (Table 9.8). These are national targets that are also being adopted by state departments of health and have organizational as well as legal implications. The Midcourse Review (2010) identifies the progress made since establishment of the goals and targets. The review found difficulties in the systematic evaluation of actions and in establishing that some medical conditions are related to the job. The review also found a lack of awareness of prevention methods and risks for some conditions that are otherwise preventable. There is renewed effort in activities such as research, surveillance, new preventive measures, and information dissemination and training.

OCCUPATIONAL INJURY

The majority of employed healthy individuals who are able to contribute to society on a daily or weekly basis spend a large portion of their lives at work. Spending extensive amounts of time in the workplace allows for the possibility of occupational injury; however, risks and type of injury are, as one would expect, influenced by work category or the task being carried out. New and interesting technological tools are being developed in an effort to prevent or limit an employee's physical distress (Box 9.33). Thus, the same tasks can be achieved with significant less risk of injury, which in turn reduces workers' compensation claims as well as lost workdays. In the USA, major progress has been made in workplace safety. While this is a great achievement, the importance of this public health measure crosses all borders, and there are advances to be made in occupational health globally. Progress in reduced mortality from occupational injuries is shown in Figure

9.6. The introduction of federal workplace safety initiatives was associated with a reduction of the deaths in miners; this is one of the greatest public health achievements of the twentieth century (Figure 9.7).

TOXICITY AT THE WORKPLACE AND IN THE ENVIRONMENT

Toxic substances are widely used in industry, not only in manufacturing but also in services such as laboratories, and they constitute a major concern in both occupational and environmental health. Extensive information on toxic substances is published by the WHO and the CDC.

Much of the concern in occupational health has been on detection, prevention, and reduction of exposure to toxic materials in the workplace, but more recently concern has increased with regard to contamination of the surrounding environment. The scientific knowledge of toxins used in occupational settings and their sources, uses, effects, actions, and target organs is extensive.

Factors that affect the toxicity of an agent include the extent and duration of exposure, and host factors such as age, gender, fitness, previous exposure, and compounding risk factors such as smoking and nutritional status. Environmental factors include temperature and air flow, as well as the physical and chemical properties of the toxic agent. The following examples of toxic substances and the history of measures to control them illustrate the complexity of this problem.

Lead

Lead is a mineral with thousands of applications because of its plasticity and softness. Lead poisoning has been a worker hazard since ancient times. Lead enters the body

TABLE 9.8 US Health Targets in Occupational Safety and Health for 2020

Subject	Previous (Baseline)	Target
OSH-1: Reduce death from work-related injuries	4 work-related injury deaths/100,000 workers (2007)	3.6/100,000
OSH-2: Reduce work-related injuries (non-fatal), resulting in medical treatment, lost time from work, or restricted work activity	4.2 injuries/100 full-time workers (2008)	3.8/100
OSH-3: Reduce the rate of injury and illness cases involving days away from work due to overexertion or repetitive motion	29.6 injury and illness cases/10,000 workers	26.64/10,000
OSH-4: Reduce pneumoconiosis deaths	2430 pneumoconiosis deaths (2005)	2187 deaths
OSH-5: Reduce deaths from work-related homicides	628 work-related homicides (2007)	565 deaths
OSH-6: Reduce work-related assaults	8.4 assaults/10,000 workers (2007)	7.6/10,000
OSH-7: Reduce the proportion of people who have elevated blood lead concentrations from work exposures	22.5/100,000 employed adults have elevated blood lead concentrations	20.2/100,000
OSH-8: Reduce occupational skin diseases or disorders	4.4 occupational skin diseases/100,000 workers (2008)	4/10,000
OSH-9 (Developmental): Increase the proportion of employees who have access to workplace programs that prevent or reduce employee stress		
OSH-10: Reduce new cases of work-related, noise-induced hearing loss	2.2 new cases of work-related hearing loss/10,000 workers (2008)	2/10,000

Note: OSH= occupational safety and health.

Source: Healthy People: Occupational health and safety [updated 26 July 2012]. Washington, DC: US Department of Health and Human Services. Available at: <http://www.healthypeople.gov/2020/topicsobjectives2020/objectiveslist.aspx?topicId=30> [Accessed 18 August 2012].

through inhalation and ingestion, affecting the gastrointestinal, nervous, hematological, and circulatory systems. It is associated with intestinal colic, encephalopathy, delirium, and even coma in its acute forms. Chronic forms of plumbism or lead poisoning cause mental dullness, headache, memory loss, neurological defects (wrist drop), anemia, and a blue line on the gums.

Lead toxicity has been a traditional health problem of glaziers and potters because of lead use in the manufacturing process. Wines or rum produced and stored in lead containers or in pewter (lead–tin alloy) utensils were known to be associated with the “dry gripes” in the seventeenth and eighteenth centuries. The Devonshire colic, described in 1776 by George Baker, was widespread for more than 100 years in parts of England where cider was made and stored in lead containers.

Lead toxicity and excess exposure in the workplace remain problems in the USA. Lead-induced hypertension, neuropathy, carcinogenesis, reproductive damage for men, and abortion for women are the major toxic effects. In 1995, CDC’s NIOSH Adult Blood Lead Epidemiology and Surveillance Program, which monitors elevated blood levels among adults, reported a continuing hazard of work-related exposures as an occupational hazard in the USA. Studies of lead exposure in industrial settings in the USA have shown widespread exposure above permissible exposure limits, in the traditional high-exposure industries such as primary and secondary lead smelting, battery and pigment manufacturers, brass/bronze foundries, and 47 other industries.

Workers with the highest exposure jobs throughout industry were painters.

Occupational exposure continues to be an important source of lead toxicity. OSHA standards promulgated in 1978 came at a time when lead prices dropped, reducing the number of producers and the degree of compliance overall.

Concern over lead toxicity evolved from strictly occupation-related to environmental toxicity in which both the exposed worker and the general population are adversely affected by this widely used metal. In 1997, the CDC adopted a BLL standard of less than 10 µg/dl, a level at which a negative effect on cognitive development is recorded. The US NHANES found that between 1976 and 1980, and 1980 and 1991, geometric mean BLLs of people aged 1–74 in the USA declined from 12.8 µg/dl to 2.9 µg/dl, and even further in 1991–1994 to 2.3 µg/dl. The geometric mean BLL for the US population aged above 1 year decreased by 30 percent from 1991–1994 to 1999–2002; the prevalence of elevated BLLs decreased by 68 percent overall and by 64 percent for children aged 1–5 years, largely due to very active regulatory and inspection services of low-income housing and lead paint removal efforts in housing rehabilitation (CDC, 2005).

Despite major improvements (see Box 9.17), some 1.7 million children aged 1–5 in the USA still have BLLs above 10 µg/dl. Further progress in BLLs will require reduction in lead hazards in housing and reduced contact with lead-contaminated dust, house paint lead, and worksite exposure. Work-related and environmental lead exposures continue to

BOX 9.33 Occupational Safety in the USA: Achievements of Public Health in the Twentieth Century and Between 2000 and 2011

The Centers for Disease Control and Prevention designated workplace safety as one of the ten great achievements of public health in the USA in the twentieth century. In the early years of that century, workers in the USA faced high health and safety risks at work. Large decreases in work-related deaths and injuries resulted from the combined efforts of government regulators, unions, employers, scientists, individual workers, and others. Despite reductions in injury, disease, and death from these improved work conditions, “much work remains, with the goal for all workers being a productive and safe working life and a retirement free from long-term consequences of occupational disease and injury”, especially in mining and forestry (CDC, 1999).

Since 2000, progress has continued to improve working conditions, to reduce the risk of workplace-associated injuries. Patient lifting has been a substantial cause of lower back injuries among the 1.8 million US health workers in nursing care and residential facilities. Patient-handling programs introduced mechanical patient-lifting equipment, reducing by 66 percent rates of workers’ compensation injury claims and lost workdays. Investment in lifting equipment can be recovered in less than 3 years. Following widespread dissemination and adoption of these practices by the nursing home industry, US Bureau of Labor Statistics data showed a 35 percent decline in lower back injuries in residential and nursing care employees between 2003 and 2009.

The annual cost of farm-associated injuries among young people has been estimated at US\$1 billion annually. A comprehensive childhood agricultural injury prevention initiative was established to address this problem. Among its interventions was the development by the National Children’s Center for Rural Agricultural Health and Safety of guidelines for parents to match chores with their child’s development and physical capabilities. Follow-up data have demonstrated a 56 percent decline in youth farm injury rates from 1998 to 2009 (National Institute for Occupational Safety and Health, unpublished data, 2011).

In the mid-1990s, crab fishing in the Bering Sea was associated with a rate of 770 deaths per 100,000 full-time fishermen, mostly due to overloading of vessels which overturned because of their heavy loads. In 1999, the US Coast Guard implemented Dockside Stability and Safety Checks to correct stability hazards. Since then, one vessel has been lost and the fatality rate among crab fishermen has declined to 260 deaths per 100,000 full-time fishers (see Plimsoll line, Chapter 1).

Sources: Centers for Disease Control and Prevention. *Achievements in public health, 1900–1999: Improvements in workplace safety – United States, 1900–1999.* MMWR Morb Mortal Wkly Rep 1999;48:461–9. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4822a1.htm> [Accessed 17 August 2012].
Centers for Disease Control and Prevention. *Ten great public health achievements – United States, 2001–2010.* MMWR Morb Mortal Wkly Rep 2011;60:619–23. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6019a5.htm> [Accessed 17 August 2012].

be public health problems in the USA, requiring continued diligence on the part of pediatricians and internists as well as occupational and public health workers.

The Upper Silesia region of Poland, with a population of 4 million, is the site of many non-ferrous metal plants, especially using lead and zinc. In the Katowice district there are four such plants, two of which are more than a century old and have a high output of atmospheric lead, and two built in the 1960s with inadequate pollution control equipment. Although emissions of lead and cadmium from one plant reportedly fell during the late 1980s, high levels of blood lead and cadmium are found in children, and soil contamination is extensive, including high levels of contamination of vegetables. This problem is widespread in Eastern Europe.

Reduction in lead exposures has been achieved in the USA by a combination of legislation and professional and social pressures, resulting in the adoption of lead-free gasoline, removal of lead from paints, and its substitution in many industrial practices. Awareness and active lobbying by public health-minded groups have had a beneficial effect in reducing lead toxicity in the community and workplace. The CDC in May 2012 announced a change in the “level of concern” from 10 µg/dl to 5 µg/dl. The APHA welcomed this change, which will increase the number of children in the USA needing follow-up from 100,000 to 450,000. However, the 2011 budget for the US lead screening program was reduced from US\$29 million to US\$2 million: the APHA is calling for restitution and even expansion of the budget. The APHA is promoting a wide-ranging program of further abatement of lead paint hazards including litigation against manufacturers, lead-safe workplaces, home renovations, and community-based prevention and health education programs (APHA, 2012).

Asbestos

Asbestos is a commercial name for six different fibrous materials that have many features making them attractive for many diverse uses in commercial and military products for fireproofing, automotive brakes, textiles, cement products, and wallboard material. The fibers fragment easily and remain in the air, where they can be inhaled readily by workers or others exposed to the asbestos-containing material, during its use or disposal.

Asbestos-related disease is an occupational and public health problem that grew from the rapid increase in the use of asbestos during World War II. It left a legacy of death and disease that only became apparent many years later. Fibrotic lung disease resulting from asbestos exposure was called *asbestosis* by W. E. Cooke in 1927. A subsequent British government investigation of the subject reported to Parliament that inhalation of asbestos dust over a period of years results in the development of a serious type of fibrosis of the lung, and recommended dust suppression measures. This report was followed by many

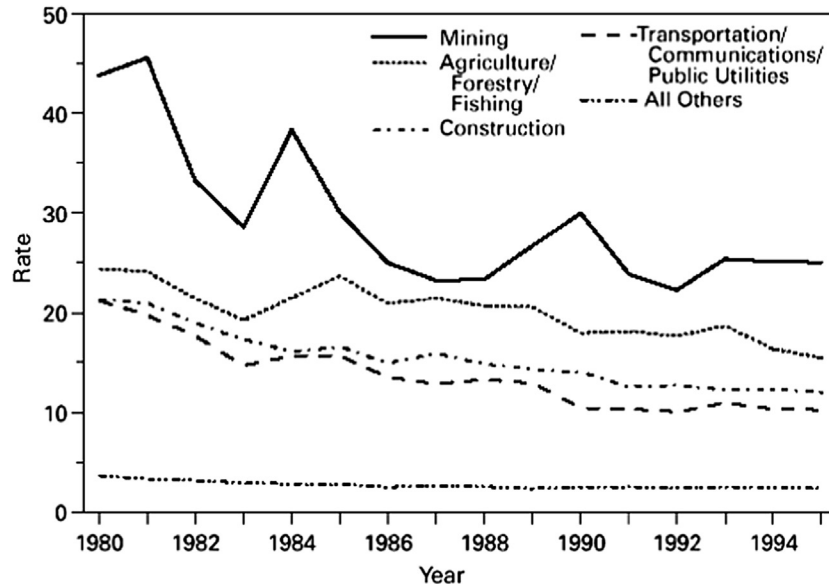


FIGURE 9.6 Occupational injury death rates per 100,000 workers, by industry, USA, 1980–1995. Note: “All Others” includes public administration, manufacturing, wholesale trade, retail trade, services, and finance/insurance/real estate. *Source: Centers for Disease Control and Prevention. Achievements in public health, 1900–1999: Improvements in workplace safety – United States, 1900–1999. MMWR Morb Mortal Wkly Rep 1999;48:461–9. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4822a1.htm> [Accessed 17 August 2012].*

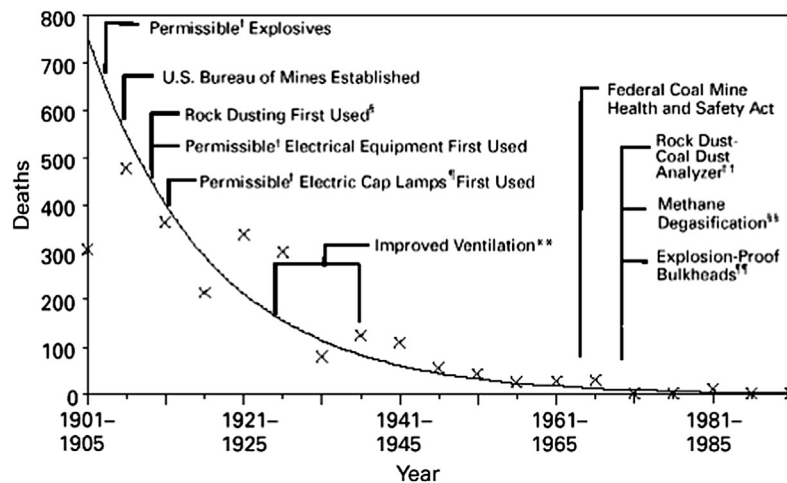


FIGURE 9.7 Public health achievements: reduction in deaths of miners with safer equipment and improved ventilation 1901–1995. Note: Each X represents the 5-year average of the number of deaths resulting from explosions; the line is a smoothed regression line through the 5-year averages. †Explosives and equipment that can be used in an explosive methane-rich environment without causing a methane explosion. §The process of applying a layer of rock dust over the coal dust, which creates an inert mixture and inhibits a coal dust explosion. ¶Lamps worn on miners’ caps. ** Ventilation improvements, including the use of reversible fans, reduce the concentration of methane and remove the explosive gas from the mine. ††A handheld monitor that provides instantaneous readings of the rock-to-coal dust mixture to ensure that it is inert. §§Techniques to remove methane from the coal bed before mining the coal. ¶¶Explosion-proof walls used to seal abandoned (mined-out) areas to protect workers in active parts of the mine. *Source: Centers for Disease Control and Prevention. Achievements in public health, 1900–1999: Improvements in workplace safety – United States, 1900–1999. MMWR Morb Mortal Wkly Rep 1999;48:461–9. Available at: <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4822a1.htm> [Accessed 27 June 2013].*

case reports and the wide recognition of the health hazards associated with asbestos exposure. During World War II, the US Navy issued minimum requirements for safety in shipyards contracting for naval work, involving some 1 million workers.

The first reports of an association between asbestos and lung cancer began to appear in the 1930s. Studies by Irving Selikoff in 1965 in New York reported high rates of lung cancer

in several large population groups of ex-shipyard workers. Selikoff and colleagues also showed a synergistic relationship between asbestos exposure and cigarette smoking (Table 9.9); namely, a greater risk of lung cancer with heavier smoking and a reduction in risk following cessation of smoking. Similar dose-related findings for lung cancer among smoking ex-asbestos workers were reported for the period 1985–90 in Stockholm Sweden (Gustavsson et al., 2002).

TABLE 9.9 Lung Cancer Death Rates (Age Standardized) for Workers Exposed to Asbestos Dust and Cigarette Smoking with Controls

Group	Asbestos Exposure	Cigarette Smoking	Death Rate	Mortality Difference	Mortality Ratio
Control	No	No	11.3	0	1.0
Asbestos workers	Yes	No	58.4	+47	5.2
Control	No	Yes	122.6	+111	10.9
Asbestos workers	Yes	Yes	601.6	+590	53.2

Note: Rates per 100,000 person-years, age standardized, on 12,051 asbestos-exposed workers followed prospectively between 1967 and 1976. Controls included 73,763 similar men in a prospective American Cancer Society study for the same decade. The number of lung cancer deaths is based on death certificate information.

Sources: Hammond EC, Selikoff IJ, Seidman H. Asbestos exposure, cigarette smoking, and death rates. *Ann NY Acad Sci* 1979;330:473–90. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/294198> [Accessed 17 August 2012].

Frank AL. Public health significance of smoking-asbestos interactions. *Ann NY Acad Sci* 1979;330:791–794. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/294223> [Accessed 18 August 2012].

Selikoff IJ. Asbestos-associated diseases. In: Last JM, editor. *Maxcy-Rosenau: Public health and preventive medicine*. 12th ed. Norwalk, CT: Appleton-Century-Crofts; 1986.

Case BW. Asbestos, smoking, and lung cancer: interaction and attribution. *Occup Environ Med* 2006;63(8):507–508. doi: HYPERLINK "<http://dx.doi.org/10.1136/oem.2006.027631>" \t "pmc_ext" 10.1136/oem.2006.027631 PMID: PMC2078131

Gustavsson P, Nyberg F, Pershagen P, Patrik-Schele P, Jakobson R, Plato N. Low-Dose Exposure to Asbestos and Lung Cancer: Dose-Response Relations and Interaction with Smoking in a Population-based Case-Referent Study in Stockholm, Sweden. *Am J Epidemiol* 2002;155:1016–22.

Available at: <http://aje.oxfordjournals.org/content/155/11/1016.full.pdf+html> (accessed 22.12.2013)

The US Toxic Substances Control Act of 1976 placed the responsibility for harmful chemicals, including asbestos, on those who would profit from their sale. The long time-lag between the first reports of asbestos-related disease followed by definitive studies and implementation of control measures raised questions as to the way in which occupational health functions. As a result of these studies and the regulatory responses by federal legislators, there was a fourfold reduction in asbestos use in the USA from 1972 to 1982. In 1986, the US Asbestos Hazard Emergency Response Act reinforced federal regulation of asbestos use.

Asbestos exposure is accepted as the cause of mesothelioma, a highly malignant cancer of the chest or abdominal lining. The latency period may be 20–30 years or more, and the risk of this disease as well as lung cancer is related to the extent of exposure and to cigarette smoking. The exposure may occur in asbestos-cement production, shipyard workers, garage workers exposed to brake linings, plumbers, and construction workers using asbestos-based products.

During the 1980s, concern was expressed that asbestos was being exported to developing countries lacking the regulatory mechanisms of the developed world. In the 1990s, there was still some concern that asbestos products manufactured in developing countries were being imported to developed countries. In 1999, the EU effectively banned the use of asbestos products. In March 2012, CDC's NIOSH stated: "Although the use of asbestos and asbestos products has dramatically decreased in recent years, they are still found in many residential and commercial settings and continue to pose a health risk to workers and others".

Silica

Silica is a non-metallic element occurring in rocks, clay, and sand. It is widely used in the manufacture of glass and clay

products. It is inert but becomes biologically active when inhaled as dust. It causes silicosis, a progressive disabling pulmonary fibrosis.

Silicosis is one of the oldest known occupational diseases, affecting miners in particular. It was described in ancient Greece and Rome as the "fatal dust". Silica occurs in minerals and rocks throughout the world either as free silica or combined in quartz, flint, or sandstone. Mining, tunneling, stone cutting, quarrying, iron and steel works, sandblasting, brick making, polishing of stone, glass, and metals, and many other industries expose workers to inhalation of silica dust (Box 9.34).

Silicosis is a condition of massive fibrosis of the lungs resulting from prolonged inhalation of silica dust. It is classified as a pneumoconiosis, a general inflammatory fibrotic lung condition caused by inhalation of dust particles. This condition can progress through mild symptoms to shortness of breath, with radiological evidence of pulmonary consolidation and concomitant tuberculosis. Silica is also associated with lung cancer, tuberculosis, and bronchial airway diseases. It is also associated with development of autoimmune disorders, chronic renal disease, and other adverse health effects.

Studies of hard coal miners in the nineteenth century documented the effects of silicosis. By 1918, English workers could receive disability compensation for silicosis and tuberculosis. In the 1920s and 1930s in the USA, studies showed silicosis in cement production workers, anthracite miners, tunnel workers, lead-zinc miners, and other hard rock miners. In the mid-1930s, an estimated 700 US workers died as a result of construction of the Hawk's Nest Tunnel in Gauley Bridge, Fayette County, Virginia, leading to compensation laws covering workers with silicosis. At present, there is still controversy over legally enforceable standards, and the problem remains difficult to prevent.

BOX 9.34 Ramazzini on Silicosis, 1700

"We must not underestimate the maladies that attack stonecutters, sculptors, quarrymen and other such workers. When they hew and cut marble underground or chisel it to make statues and other objects, they often breathe in the rough, sharp, jagged splinters that glance off, hence they are usually troubled with cough, and some contract asthmatic affections and become consumptive."

Source: Quoted in Hunter D. *The diseases of occupations*. 4th ed. London: English Universities Press; 1969.

Cotton Dust (Byssinosis)

Cotton dust has been a common cause of COPD among long-term workers in textile industries, widespread in the USA until the 1960s. OSHA promulgated new standards in 1978 based on assessment of the potential of improved ventilation and filtration, and improved machinery use. The industry at that time was in the process of replacing old equipment with modern and more automated machines, which gave improved production speed, more effective use of floor space, reduced labor input, and a higher quality product, along with lower dust levels. The technical and economic feasibility of the higher standard was correct, and compliance by industry exceeded early expectations at about one-third of anticipated costs.

Vinyl Chloride

Vinyl chloride is a colorless, flammable gas with a faintly sweet odor. It is an important component of the chemical industry because of its flame-retardant properties, low cost, and many end-product uses. It is also a carcinogen causing liver, brain, and lung cancer, as well as spontaneous abortion. Vinyl chlorides are dangerous primarily when inhaled or ingested. Vinyl chloride usage increased from the 1930s and more dramatically after the end of World War II until the 1970s. In the 1960s, polyvinyl chloride (PVC) was shown to be associated with Raynaud's phenomenon and later with malignancies, including hemangiosarcoma of the liver.

The carcinogenicity of PVC was established as a result of the review of all evidence in 1974 by the US Office of Technology Assessment and OSHA. Scientists concluded that there was no safe level of exposure to vinyl chlorides. OSHA adopted 1 part per million as the maximum possible dose. While the risk assessment issues are still controversial, reduction of exposure to workplace carcinogens such as vinyl chloride is the accepted standard of modern occupational health.

Despite the industry's vigorous opposition to this reduction in permissible emission level, full compliance was achieved within 18 months by improving ventilation, reducing leaks, modifying reactor designs and chemical pathways, and using greater automation of the process. Even

more effective was a major improvement in the production of PVC using less vinyl chloride. The costs to industry of reducing exposure levels were less than 25 percent of expected costs because of unanticipated innovations in the production process.

Agent Orange

The herbicide Agent Orange, which was used widely by US armed forces in the 1960s and early 1970s during the Vietnam War to defoliate large areas of the country, contains dioxin and is carcinogenic. High levels of dioxin have been found in the breast milk, adipose tissue, and blood of the Vietnamese population. Even though sampling has not been systematic, studies carried out between 1984 and 1992 found high levels of dioxin-like contaminants (2,3,4,8-tetrachlorodibenzo-*p*-dioxin, TCDD) in blood samples of the Vietnamese population exposed to Agent Orange during the war.

Studies of effects among US veterans of the Vietnam War have not produced convincing evidence of long-term effects. Additional studies will be needed to verify effects such as increased cases of cancer or birth defects. However, court and compensation decisions have been made in favor of veterans exposed to Agent Orange despite inconclusive epidemiological evidence of its ill-effects on health.

WORKPLACE VIOLENCE

Violence is endemic in many societies and affects many organizations and institutions. Violence has become a leading cause of fatal injuries in the workplace. Violence in the health setting has an extensive history, with the first documented case in 1849 when a patient fatally assaulted a psychiatrist in a mental health care facility. Since then there have been many other studies reporting assaults, hostage taking, rapes, robbery, and other violent acts in the health care and community settings. During the 1990s, homicide became the leading occupational cause of death for females and the second leading cause, after motor vehicle accidents, for men in the USA.

Small businesses have special risk factors. Murder of small business employees in the USA and other countries has become a major occupational problem. Some workplaces such as convenience stores with few employees are at particular risk. Between 1992 and 2010 there were 13,827 workplace homicides in the USA. More than half of these violent deaths occurred in three workplace classifications, with 28 percent in sales and related occupations. Protective measures are being introduced and the OSHA provides small businesses with free safety and health guidelines and consultations on worker protection. In 2010 these covered 30,000 small businesses with 1.5 million workers (OSHA, 2013).

Shocking incidents of violence and homicide have occurred in which bombs and handguns were used in

assassinations of health workers in clinics carrying out abortions, while health workers have also been assaulted and murdered in hospitals and other settings. The US target of work-related homicides for the year 2010 was 0.4 per 100,000 workers over 16 years of age.

Homicide at work has only recently been addressed as an occupational hazard, and research in this area is in its infancy. No universal standards exist to protect workers from work-related violence, and no policy has been created to protect workers. Preventing violence in the workplace is essential and must be addressed at the national level. The California Occupational Safety and Health Authority promulgated guidelines with an emphasis on preventing violence before it occurs, by developing an effective policy to ensure workplace safety. Management and workers' organizations as well as the health system share responsibility. Prevention of drug, alcohol, and sexual abuse or exploitation at work is vital to eliminate workplace violence.

OCCUPATIONAL HEALTH IN CLINICAL PRACTICE

The clinical physician should be aware of the patient's occupation and previous work history. The inclusion of questions related to workplace factors of current or past employment (Table 9.10) may be crucial in the investigation of patients; without this information it may be impossible to determine the cause of the disease. The health care provider should be aware of industries in the community and their potential hazards. The clinician is particularly important because he or she may be the first to see index cases of toxicity. The clinician should ask simple questions, such as the following: What is your job or hobby? What do you do at work? Are you exposed to any chemicals at work or at home? Are there others at work with similar exposure and similar symptoms? How long have you been exposed to these chemicals? Clinical suspicion is the key to finding a potential toxic cause to a set of symptoms, and may uncover a wider public health problem.

INSPECTING THE PLACE OF WORK

The public health authority responsible for health at the place of work may be under the authority of a Ministry of Labor or under a public health authority. Site inspection provides a guide to management and workers for safety and health issues. Non-compliance with federal, state, or local standards should lead to regulatory action to correct deficiencies and should include, if necessary, punitive damages to management. Examination of the worksite involves on-site observations as listed in Table 9.10. The inspection should be documented and made available to management, workers, and follow-up inspections.

RISK ASSESSMENT

Identifying and quantifying occupational and environmental risks may be difficult, but clinical or public health observations, supplemented by epidemiological analysis, can identify toxic or carcinogenic factors that can be reduced or eliminated by public health intervention. High levels of awareness by clinicians of potential health effects from environmental or occupational exposures can help in the identification of index cases just as in infectious disease, leading to an investigation and removal of the cause. Similarly, epidemiological small area analysis can identify populations at high risk for cancers or other toxic effects, providing localization for further investigation.

The establishment of dose-response relationships requires well-conducted observational studies. Some studies may be so insensitive as to dismiss risks that are at low levels of statistical significance, but still represent preventable risks that can be sufficient to warrant compensation. This was the case for veterans in the USA who were exposed to Agent Orange in Vietnam in the 1960s and those suffering from effects attributed to toxic exposures in the Gulf War in 1991 and Iraq War (Second Gulf War) of 2003–2008.

Regulatory and compensation decisions must often be made in the face of inconclusive or contradictory evidence from epidemiological studies. In the 1960s, the FDA used the Delaney Clause applied to food additives or coloring in which any degree of ill-effect noted in animal studies was enough to disqualify a drug from acceptability, but this has not become an accepted legal standard. The topic remains one of controversy and contradiction, with cases providing precedents that affect future court and regulatory decisions. The contribution of epidemiology to resolving such issues also remains controversial.

PREVENTING DISASTERS IN THE WORKPLACE

A disaster in a workplace can affect the workers and the surrounding community. The major responsibility for prevention lies with management, but the worker and society also have roles in the process. Prevention involves education of workers and management, and constant vigilance. Government has the overall responsibility to legislate and enforce standards, safe conditions of work, and control of toxic materials, and to ensure fair compensation for injury or disease. The simple qualitative observations listed in Table 9.11 can provide a useful picture of the disaster management capacity of a worksite. These observations can be made by management, health professionals, and workers' representatives to monitor and promote improved worker health and safety.

The principle of "good worksite practice" is parallel to good manufacturing practices required by food and drug authorities. It is based on the concept that current standards of acceptable safety involve standards of facilities, staffing,

TABLE 9.10 Factors for Walk-Through Inspection of Worksites

Marker	Observations of Conditions, Safety Arrangements, and Effects on Workers
Sensory effects	Eye irritation, poor lighting, noise levels, metallic taste in air, visible fumes, exhaust, temperature (heat/cold)
Safety devices	Use of hard helmets, welding masks, safety shoes and clothing, ear protectors, eye and face protectors, first aid facilities, respirators, monitoring procedures
Storage	Hazardous chemical substances closets; unlabeled bottles, containers
Toilets	Cleanliness, fixtures, soap, toilet paper, waste disposal bins
Worker hygiene	Changing place, showers, lockers, clothing change
Eating place	Separate tables, cleanliness, wash-up facilities
Workers' ages	Children, teenagers, elderly, pregnancy
Workers' complaints	Headache, fatigue, dizziness, nausea, breathlessness, skin problems
Worker morale	Reflected in turnover and absenteeism
Worksite layout	Safety in movement of supplies, products, ventilation
Medical service	On-site staff, first aid, evacuation procedures
Emergency procedures	Spills, contamination, terrorist attack, communications, reporting, evacuation, staff training
Hazard control	Labeling, process recording, worker records, periodic screening
Cleanliness	Removal of waste products, oil or chemicals on floors, machines, tables
Vents, fans	Exhaust of fumes, odors, dust
Worker-management cooperation	Mechanisms for worker and management to consult and share responsibility to reduce hazards and improve performance

TABLE 9.11 Markers and Indicators of Disaster Management Capability in an Industrial Setting

Marker	Indicator
Engage key stakeholders	Ongoing consultative mechanism to develop and implement plan
Administrative	Occupational health disaster plan; access to first aid; frequent disaster drills; close supervision of subcontractors
Investigation	Thorough investigation of complaints, leaks, and spills
Monitoring workers	Monitor worker injuries, illnesses, toxic levels; use of safety measures
Technological	Fail-safe monitoring devices; real-time monitoring; minimal on-site storage; automatic alarm/shut-down devices; local incineration/neutralization
Transportation	Vehicle and container standards; driver training, fatigue, alcohol and drug abuse, traffic offenses
Information/feedback	Workers' information; right-to-know of workers and community; community disaster plan

Source: Koh D, Aw T. Surveillance in occupational health. *Occup Environ Med* 2003;60:705–10. Available at: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1740637/> [Accessed 17 August 2012].

and operational criteria. The healthful and safe worksite should be maintained and accredited on that basis.

OCCUPATION AND THE NEW PUBLIC HEALTH

Social class, often defined by occupation and education, is a key determinant of health status. A population of unskilled workers has much higher rates of coronary heart disease, strokes, and cancer, and their children have much higher rates of mortality and morbidity than higher skilled workers

or business and professional people. The evidence points to a feeling of having less control over one's own life as a major consideration. The worker who has little say in determining his or her own activities may be subject to higher stress at work, such as on the production line, or in job security, advancement, and wages. Loss of work is a key factor in increasing the vulnerability of men in particular to a variety of life-threatening conditions, including suicide, alcoholism, violence, and cardiovascular disease. The phenomenon of downsizing, or reducing the workforce, affects production workers disproportionately, but also reaches middle- and

upper-management levels, so that the danger of losing a position at an age when finding new employment is unlikely may become a real health hazard. Awareness of and responsiveness to a variety of risks associated with employment and occupation are part of health responsibility. Prevention may predominate in some situations, screening for case finding in others, and clinical management in yet others.

SUMMARY

Environmental health and occupational health are inter-related topics that are becoming increasingly prominent in the New Public Health, along with concern for global ecology. The 2013 Bangladesh incident of over 370 clothing workers burned to death in grossly unsafe and locked premises highlight the dangers of globalized industry and poor occupational health amidst poverty and poor safety measures. Safe water and waste disposal, so fundamental to public health and so successful over the past century in reducing morbidity and mortality, remain serious problems in low-income countries. Their inclusion in the MDGs, challenges that are accepted by almost all countries in the world, attests to this recognition, and progress is being made.

The problems of the environment have become more complex in recent decades as scientific consensus on global ecological concerns has emerged. These include global warming, hazards associated with nuclear accidents on the scale of Chernobyl and Fukushima, and frequent chemical disasters. Water safety is compounded by water shortages and threats of desertification in large parts of the world where droughts are common. Concern for the environment and the worker often clashes with a desire for economic growth, especially in poorer countries as they try to cope with rapidly increasing populations and increasing expectations of a better life.

Air pollution, climate change, deforestation, desertification, water shortages, and population growth, especially in low-income countries, can lead to environmental and human tragedies on a vast scale. In higher income countries, environmentally friendly lifestyles, urban planning, land and water pollution cleanup, and oil spills are continuing issues at the forefront of public health in collaboration with environmental and occupational health protection agencies.

Important progress has been made in the management of water, waste products, toxic wastes, and air quality standards, especially since the 1970s. Workers' health and safety have improved dramatically over the past century in the industrialized countries. However, some of these gains are at the cost of moving hazardous materials and working conditions to newly industrializing or developing countries in the global economy, along with widespread outsourcing of low-skilled work in dangerous conditions to countries rife with corruption.

Even a vigilant health sector is, by itself, incapable of dealing with the problems of the environment and of occupational health. It requires many levels and agencies of

government as well as the support of public opinion. The role of the public health community is to act in the professional and advocacy roles with intersectoral cooperation to address these complex and vital issues. Epidemiology provides tools to measure mortality, morbidity, and physiological changes that may occur as a result of environmental damage, but these may not be sufficiently rapid or sensitive. Both epidemiology and testing technology are improving steadily, providing hope for standards that one would expect to contribute to a cleaner, safer, and more aesthetically pleasing environment. Technical advances in water and waste management are becoming available and can play an important role in global health progress.

The environment affects everyone, but the poor more so, for many reasons. Work, or lack of satisfactory work, occupies a large portion of a person's time and energy. The workplace is also the location of many activities of daily life, including diet and physical activity. Policy makers, employers, and workers all need to take this into account in developing worksite conditions, management, access to health services, life habits, nutrition, and planned activities, along with safety and risk reduction for the benefit of both employer and worker, to protect the health of workers. This is increasingly important as more people are employed in knowledge-based industries, and with the aging of society, fewer workers are available to perform unskilled jobs. For these reasons, health targets cut across all aspects of society, including environment and workplace health.

The New Public Health includes long-standing public health issues of the environment and occupational health, but widens the field to include clinical services, the community, and the individual. Everyone needs to be involved in healthy public policy, in case finding, and in documenting the results of workplace and environmental risks. For a society there are choices to be made in creating a less toxic and hazardous environment, including private versus public transportation, jobs in industries with toxic emissions, and producing energy from fossil fuels or from nuclear sources.

Substitutes for toxic materials and an increased level of social consciousness are needed to reduce the gross pollution that was the price of industrialization over the twentieth century. Equally challenging is the need to prepare and deal with natural and human-caused disasters that may involve conventional explosives or biological, chemical, and even nuclear methods of destruction.

Achievements made with the MDGs to reduce poverty and ensure environmental sustainability will need to be carried beyond the current target of 2015. Avoiding the impact of the most damaging changes to the climate requires global action in the decades ahead. The financial resources and technological capabilities exist but implementation requires a sense of urgency, public interest, and political will to make deep cuts in greenhouse gas emissions. How global society addresses the issues of global warming will be crucial to our future as

unrestrained pollution and anthropogenic destruction will be too great a burden to bear. Investment in a healthy environment and work settings is a health, economic, and quality-of-life issue for each community, each country, and the entire planet.

NOTE

For a complete bibliography and guidance for student reviews and expected competencies please see companion web site at <http://booksite.elsevier.com/9780124157668>

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