Disasters and Public Health

Planning and Response

Second Edition

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About the Authors

Bruce W. Clements, MPH

Bruce W. Clements serves as the Preparedness Director at the Texas Department of State Health Services and previously held the Preparedness Director position for the state of Missouri. In this capacity, he provides leadership and oversight for public health and healthcare systems preparedness programs and initiatives in Texas. These efforts combine the disciplines of public health, clinical medicine, emergency management, and public administration to build a statewide public health and medical emergency response infrastructure. In addition, he manages associated preparedness grants and provides direction for state planning, training, and exercises.

Mr. Bruce W. Clements has extensive experience in forming and managing emergency response teams and activities including: an environmental health team that responded to the Midwest floods of 1993; a public health team deployed in 1997 to Hurricane Mitch in Honduras; Missouri state responses to ice storms, floods, and tornadoes; and Texas state responses to hurricanes, wildfires, Ebola, West Nile Virus, the H1N1 influenza pandemic, and the West, Texas fertilizer plant explosion. He served on Missouri Task Force 1, Urban Search and Rescue Team, and the Missouri-1 Disaster Medical Assistance Team. During a 23-year career in the US Air Force and Air National Guard, he served as a Disaster Preparedness Specialist responding to a wide range of emergency situations, and as a Public Health Officer. Bruce received a Master of Public Health degree from Saint Louis University in St. Louis, Missouri and served as the Associate Director of the Saint Louis University, Institute for Biosecurity from 2000 to 2005. He has Adjunct Instructor appointments at the Texas A&M Health Sciences Center, College of Medicine (Round Rock, TX) and the Texas A&M Health Sciences Center, School of Public Health. He has published a variety of articles, books, and book chapters on preparedness. He has also lectured extensively on preparedness topics for over 25 years.

Julie Ann P. Casani, MD, MPH

Dr. Julie Ann P. Casani is the Director of Public Health Preparedness and Response in the North Carolina Division of Public Health. This branch coordinates the preparedness system for 85 Local Health Departments and 4 regional offices. In addition to planning activities at the local, regional and state level, this branch is responsible for providing public health coordination, subject expertise, and support to local health departments responding to and recovering from hazards such as hurricanes, pandemic influenza, and contaminating events. From 1999 to 2006, she was the Preparedness Director at the Maryland Department of Health and Mental Hygiene. Her office was lead on the anthrax events of 2001, implemented a number of enhanced health surveillance systems for bioterrorism including BioWatch and the National Capitol Region Syndromic Surveillance Project, and developed and implemented the Smallpox Preparedness and Response Program. She is Adjunct Associate Professor at North Carolina State University where she instructs in Global Public Health, Agriculture Security, and One Health. She has been a policy and health practice consultant to several national workshops and committees in weapons of mass destruction for federal and state agencies, serving on 3 Defense Science boards. She was a member of the Homeland Security Science and Technology Advisory Committee for the Department of Homeland Security.

Dr. Julie Ann P. Casani practiced clinical Emergency Medicine in the Johns Hopkins system from 1983 until 2001. She has been actively involved in emergency medical services since the 1970s, serving at every level from ambulance provider to an appointed member of the Maryland State EMS Board.

Dr. Julie Ann P. Casani received her medical degree from New York University School of Medicine and her Masters in Public Health from Johns Hopkins Bloomberg School of Public Health.

Foreword

It was with great pleasure that I recently received a request from Bruce W. Clements to write a forward to his new book. Bruce and I have known each other for a decade beginning during his tenure as the Public Health Preparedness Director for the state of Missouri and I was the Assistant Secretary for Preparedness and Response at HHS. We have both moved to different roles since that time but have maintained an active personal and professional connection based on great respect. His request was spurred by the writing of a new edition of his excellent book, *Disasters and Public Health: Planning and Response*.

The original book, published in 2009, was a sorely needed reference and basic text for those who were more engaged in the critical work of preparing for and responding to disasters, natural or manmade, that have an impact on the public health and medical well-being of communities. The original edition brought together, in a rational and comprehensive manner, the essential knowledge needed to plan for effective interventions involving medical and public health assets acting as a unified set of functions. It was a necessary text, because most of us in public health and medical disciplines had little or no experience in actively participating in disaster response and preparedness planning.

Like many of my colleagues in the field, my professional experience was initially focused on clinical activities in support of patient care. I also had the opportunity to become actively engaged in public health planning and interventions since I had spent most of my career in Indian Health Service, where we had the mission of elevating the health status of American Indians and Alaska Natives to the highest level possible. That mission required application of evidence-based best clinical practices in partnership with community-wide public health programs targeting preventable disease. For example, environmental programs to provide clean water were partnered with immunization efforts and best practices in providing maternal and child medical services to reduce infant and maternal mortality and morbidity. But these day-to-day medical and public health activities are very different than the operational approach used in disasters. I discovered this in the late 1990s and early 2000s as I was deployed to a variety of disaster-related events.

I was not fully prepared to deal with the needs of Kosovar refugees fleeing from the genocidal wars in the Balkans. Even though my life with American Indians was a result of a genocidal event, it was in a chronic status, not the acute event that played out as we provided care for the refugees. The absolute desolation of the World Trade Center and the resulting boundless grief of the people of New York were of a magnitude I could never have imagined. Empowering Iraqi people after the terror of combat and the ongoing uncertainty of death clarified the need to push forward public health and medical capabilities despite constant disruption. The population impacts of hurricanes Katrina and Rita were characterized by a need to rebuild systems large and small during and after chaos. In all of these events, the desire to step back and reason had to be tempered by the need for action.

In a disaster environment, the need to act swiftly to save lives, reduce the burden of suffering, and speed recovery requires well-thought-out plans on how to best use the human and material assets to achieve the desired outcome most efficiently and effectively. While it may seem like much of that might be intuitive and straight forward since our work in public

health is a process of evaluating risks to population health and implementation of programs to mitigate that risk. But the disaster challenge is significantly different. The threats are often fast moving, unexpected, and acute. The local capabilities and assets are likely to be in disarray. The compressed time frames and high expectations of a community for appropriate and timely response do not allow for the full deliberative processes, using science principles and insights, to which we are accustomed in our daily activities. Decision making must be immediate and it must be right. Last, we must work coherently with other responders in the unfamiliar terrain of public safety, the energy sector, transportation sector, and others who are experienced in planning and executing complex tactical and operational interventions.

The past 15 or so years have pushed public health and medical professionals into a more engaged role in preparedness and response. The events of 2001, especially the anthrax event that affected not only the Senate offices in Washington, DC, but also others in a wide geographical area, taught us that unfamiliar infectious diseases may be a real and significant population threat. The events of hurricanes Katrina and Rita demonstrated that natural disasters have significant public health and medical impacts. The failure to deliver a well-thought-out, comprehensive response in those events also pointed out the need for better and more coherent and collaborative planning in response. There have been some books in the last decade that have described these events. The first edition of *Disasters and Public Health: Planning and Response* was the first effort to organize the lessons learned in a coherent manner.

Gratifyingly, significant progress has been made since the release of that edition as we dealt with H1N1, a variety of natural disasters such as Hurricane Sandy, and most recently our experience with the Ebola events in West Africa. The analysis of the information from these events has begun to offer more evidence for interventions that allow for more rational planning. Federal policies have changed since 2008. Many programmatic changes have been made at the state and federal levels. Funding has been reduced at both the federal and state levels. Preparedness planning has focused more specifically on implementing various capabilities that have an evidence base. There has been an increased emphasis on building coalitions, especially in the medical arena, to make more effective use of the resources that are available to address documented gaps in medical surge capabilities. Awareness of mental health needs in a disaster and during the recovery period have also become more fully recognized. Accordingly, chapters that explore these issues have been developed and added to the current edition.

Perhaps the most engaging new chapter to me is the discussion of community disaster resiliency. There has been much discussion of this notion over the past few years. Although many (including me) recognize its critical importance, many (again, including me) are unclear as to what community disaster resilience means and how it may be measured and improved. The chapter authored by Tal Fitzpatrick offers great insight. Ms. Fitzpatrick, an Australian, offers concise description of the concept, and she provides approaches to measurement of resiliency that are most useful in assessing needs and interventions that may benefit community disaster resilience. Our colleagues in Australia have devoted much time and effort to this area and their work will benefit the field practitioner. Growing up in an American Indian community, I learned early the value of a "whole of community" effort in perpetuating the core of a society through its language, religious, and social elements and institutions. This chapter resonates with those early lessons for me and shows how that strength can be nurtured and empowered.

As in the prior edition, I believe that the reader will find that what will be learned is well identified and delivered. The chapters demonstrate the real improvements and sophistication that has occurred in public health planning and response efforts. It is very uplifting to see that a coherent field of knowledge is developing, and for those trying to make sense of it all, this book will be especially useful. Our profession provides many challenges, but disasters are a real growth experience. The willingness to accept our limits humbly, while doing all in

our power to use the science that informs us and the experience of operational processes in real time, requires planning and community inclusion ahead of events if we are to save lives, reduce the burden of suffering, and speed recovery. I think that you will find that this book will lead you to the rational anticipation of risks (common and uncommon) and opportunities to meet those goals.

Many thanks to Bruce and his co-authors for their diligence in identifying the available evidence based approaches. Thanks also for organizing the information in a manner that lends itself to easy understanding and application. There is much more to do in applying science methodologies to the understanding of risks and responses, but the state of the art is well captured in the pages that follow. Enjoy and learn…

W.C. Vanderwagen, MD
RADM USPHS
Retired Assistant Secretary, Preparedness and Response,
HHS 2006–2009
Columbia, Maryland
August 2015

Acknowledgments

First and foremost, thanks to my wife Stacey and sons Brandon, Brett, Brock, and Bryce for their sacrifices and encouragement throughout the updating of this book. Dr. Julie Ann P. Casani, I'm grateful for your willingness to join me in writing this second edition. Your public health and medical education and experience brought tremendous insights. Tal Fitzpatrick, author of Chapter 3, Community Disaster Resilience, I searched for the most practical and innovative community resilience programs in the world and found one in Queensland, Australia. Thank you for your willingness to write about it in this text. Lisette Osborne, this book would not have been possible without your editing and support. Rebecca Dougherty and Dana Birnberg, thanks for sharing your insights. Brock Clements, I appreciate your graphic design support. Dr. Craig Vanderwagen, you have inspired and mentored me in this field for nearly a decade. Thank you for your leadership and your kind words in the Foreword. Also, thanks to the Texas Department of State Health Services leadership and preparedness staff, including Jeff Hoogheem and Barbara Adams; and the past and present preparedness program staff at the Centers for Disease Control and Prevention (CDC). Special thanks to Christine Kosmos, Director, Division of State and Local Readiness, Office of Public Health Preparedness and Response, for serving as an outstanding leader and visionary in our profession and to Jeff Bryant, Director, CDC Division of Emergency Operations for your contributions to preparedness and advice on this second edition. Doris Brown, Director, Center for Community Preparedness, Louisiana Department of Health and Hospitals, and Scott Sproat, Chief, Emergency Preparedness and Response, Oklahoma State Department of Health, thank you for your input and suggestions. Additional thanks to my fellow Directors of Public Health Preparedness; Dr. Ali Khan, Dean, University of Nebraska Medical Center, College of Public Health; Dr. Greg Evans, Dean of the Jiann-Ping Hsu College of Public Health at Georgia Southern University; colleagues I previously worked with in Missouri including Julie Eckstein and Nancie McAnaugh; and my friends Marc Eric, Vered Kater, George Oakes, Fletch Wiley, and Michael Gotcher. The Association of State and Territorial Health Officials plays a vital role in US public health preparedness activities, and I'd like to thank Jim Blumenstock, Gerrit Bakker, and Jennifer Lumpkins for all they do for the state preparedness programs. It takes a team to put a book together and we have been so fortunate to have an outstanding team from Elsevier supporting us, including Hilary Carr, Sara Scott, and Mohanapriyan Rajendran. Thank you for bringing this all together.

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There are so many people—friends, family, mentors, colleagues and patients—who have guided me through my life, through my career, and in writing this book that I would need a book just to thank and recognize all of you. Even the smallest of interactions can have huge ripples… Bruce, many thanks for inviting me to complete one of my bucket list items. He has mentioned so many people already, and one of the things he taught me in coediting this book is keep it succinct and do not repeat anything. I would like to specifically thank Dr. Georges Benjamin, who lit a spark and mentored me through the earliest of stages in this most wonderful phase of my life. My eternal gratitude goes to Harriet Goldberg and my parents, who taught me to shoot for the stars. Oops, they forgot to teach me how to stop! To Frank, my husband, and Chris, my son, thank you for all of those weekends we didn't enjoy Raleigh as much. Many thanks to Jeanine Schultz and Manal Khan for their assistance on the At Risk Population framework and chapter. For everyone else, please do not be slighted if not mentioned directly; you know I carry it in my heart and in my work.

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Thanks to everyone who picks up this book and pursues more information on public health preparedness and response. Those working in this field are anonymous heroes. The full impact of their efforts will never be fully known. They are dedicated to protecting their constituents who are our families, friends, neighbors, and neighborhoods. Also, to those partners working in related activities including emergency management, laboratory, epidemiology, infectious disease, mental health, etc., and those taking their first steps toward this exciting and rewarding field—thank you!

1

Public Health Preparedness History and Policy

OBJECTIVES

- Describe the roots of public health preparedness programs in early US history.
- Explain how war and terrorism have influenced public health preparedness.
- List key activities required by the 2002 CDC Cooperative Agreement on Public Health Preparedness and Response for Bioterrorism.
- Explain the events influencing the expansion of the focus of public health preparedness from bioterrorism to all-hazards.
- Describe the significance of the 2006 Pandemic and All-Hazards Preparedness Act (PAHPA).
- List the major changes introduced by the 2013 Pandemic and All Hazards Preparedness Reauthorization Act (PAHPRA).
- Describe the components of the 2015 US National Health Security Strategy.
- List the public health preparedness capabilities shared with healthcare systems.
- Summarize the role of nongovernmental professional associations in public health preparedness policy development.
- List several key accomplishments in building public health preparedness infrastructure since the 2001 terrorist attacks in the United States.

The US public health preparedness policy journey provides a road map for other nations developing similar programs. The origins of public health preparedness go back to the earliest responses to infectious disease outbreaks. Today a wide range of sociopolitical factors serve as additional influences. This chapter provides a high-level summary of the history and events influencing current US policies related to public health preparedness.

The Early Years

Public health and healthcare preparedness programs are rooted in history, law, and policy development. The preamble to the US Constitution laid the groundwork for national preparedness initiatives when the framers of the Constitution stated the role of government is to "…insure domestic tranquility, provide for the common defense, promote the general welfare…". All three of these requisite Constitutional values are supported by public health preparedness. In 1798, shortly after the Constitution was adopted, the second US president, John Adams, signed into law the "Act for Relief of Sick and Disabled Seamen." This legislation established maritime hospitals to care for American merchant seamen

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and created the Marine Hospital Service. The greatest public health challenges of the 18th century (1700s) arrived on the shores of America through sailors, merchants, and immigrants carrying diseases from around the world. These public health threats placed the Marine Hospital Service at the forefront of public health emergency preparedness and response. The Marine Hospital Service became a national hospital system in 1870 and developed into a uniformed military service to coordinate the medical officers. It was led by a national senior official whose office eventually became the Office of the Surgeon General (USPHS, 2015; OSG, 2015). The Marine Hospital Service eventually became the Public Health Service. Throughout the 19th and early 20th centuries, Public Health Service officers served on the front lines against epidemics, including challenges such as smallpox and yellow fever.

As the US Public Health Service evolved on a national level, local and state health departments were established from the late 1700s through the 1800s. For example, in 1805 an ordinance was passed by New York City's Common Council establishing the New York City Board of Health. The Board of Health was led by the mayor and comprised elected city officials. The creation of New York City's Board of Health occurred in response to a series of yellow fever outbreaks over a 10-year period (1795–1805) in New York City (Jones, 2005).

Early public health agencies established policies to address sanitation issues. The sanitary movement started in Europe in the late 1700s. The early years of the industrial revolution ushered in a downward spiral in sanitation conditions across industrialized regions. This movement spread from Europe to the United States and became the primary focus of urban public health agencies throughout much of the 18th century. The movement was spurred on by the regular occurrence of major disease outbreaks, including cholera and yellow fever (Duffy, 1992). The progression of science and the increased understanding of

FIGURE 1-1 Health examination of immigrants at Ellis Island. *Office of the US Public Health Service Historian.*

infectious disease led to the bacteriological era (1875–1950) (Rosen, 1958). Public health infrastructure has its origins in this era, including establishment of the foundations of public health disciplines such as epidemiology, environmental health, and laboratory science. One example of the application of this infrastructure is shown in Fig. 1-1.

Establishing Modern Public Health Infrastructure

President Franklin D. Roosevelt signed into law the "Public Health Service Act" on July 1, 1944. This legislation combined and markedly revised all existing legislation relating to the Public Health Service. A year prior to the Public Health Service Act, President Roosevelt had ordered the establishment of the US biological weapons program. A new era of state-sponsored biological warfare had begun, and the 1944 Public Health Service Act was considered a part of US defense.

> *In establishing a national program of war and postwar prevention, we will be making as sound an investment as any Government can make; the dividends are payable in human life and health.*
>
> *US President Franklin D. Roosevelt at the signing of the 1944 Public Health Service Act (Roosevelt, 1944).*

The growing biological warfare threat also prompted Great Britain to stockpile medical countermeasures, expand lab capacity, and initiate their own offensive program (Martin et al., 2007). Other nations, including Japan, were carrying out secret biological weapons programs during World War II. The war also prompted a boost in public health infrastructure. This would not be the last time an expansion of US public health infrastructure resulted from a national security threat. It would be seen again in 2002 following the 9/11 terrorist attacks on the United States during 2001 and the subsequent mailing of letters carrying *Bacillus anthracis* (anthrax) spores to US political leaders and news media.

The 1940s was a watershed decade for public health. The Centers for Disease Control (CDC) was established in Atlanta in 1946 and comprised mostly entomologists and engineers who assisted with malaria control in the Southeastern United States and World War II combat regions (CDC, 2013). Figs. 1-2 and 1-3 show the original and contemporary headquarters locations of the CDC. Two years later, in 1948, the United Nations World Health Organization was established to replace the League of Nations Health Organization (WHO, 2015). The decades which followed included dramatic progress and numerous milestones in national and global public health. The introduction of new pharmaceuticals, including antibiotics and vaccines, ushered in significant reductions in long-standing infectious disease threats such as polio, and the eradication of smallpox.

The capacity of the US public health system declined throughout the 1970s and 1980s. By the late 1980s, local, state, and federal public health agencies and programs were in crisis. The Institute of Medicine (IOM) published a report in 1988 making a strong case that public health infrastructure at all levels was deteriorating and needed renewed attention and better support from policy makers. The IOM committee comprised leading public

FIGURE 1-2 In 1946, the first CDC offices were on one floor of an office building in downtown Atlanta, Georgia.

FIGURE 1-3 Today, the CDC headquarters complex is located several miles from its previous downtown location. *Images courtesy of the Centers for Disease Control and Prevention.*

health professionals, academics, and stakeholders. The immediate crisis spurring a need for improved public health infrastructure and support was HIV/AIDS. The rapid emergence of HIV/AIDS highlighted the downfall and disarray of public health.

> *As a society we seem to assume that we are fully capable of maintaining past progress (often dramatic improvements in the public's health and longevity), of addressing current problems, and of being prepared to respond to new crises or emergent health problems. Instead, this committee has found a public health system that is incapable of meeting these responsibilities, of applying fully current scientific knowledge and organizational skills, and of generating new knowledge, methods, and programs.*
>
> *IOM Committee for the Study of the Future of Public Health (IOM, 1988).*

As public health infrastructure experienced a modest revitalization in the 1990s, new threats emerged. In addition to the ongoing threat of emerging or reemerging infectious diseases, the frequency and severity of terrorist attacks led to new initiatives which increased coordination between public health and healthcare systems. It was two such attacks occurring within days of each other on separate sides of the globe which prompted legislative action. The Aum Shinrikyo doomsday cult carried out a nerve agent attack on five subway cars in the Tokyo subway system on March 20, 1995. The attack occurred during the morning rush, one of the busiest times of the day. The liquid sarin agent was released by puncturing plastic bags placed under subway car seats. Twelve people were killed and thousands more injured by the chemical release (Seto, 2001). A decontamination exercise to prepare for such a potential attack is shown in Fig. 1-4. One month later, on April 19, a truck loaded with ammonium nitrate was used to bomb a US government federal building. The explosion at the Alfred P. Murrah Building in Oklahoma City collapsed its north wall, killing 168 people and injuring hundreds more (Fieldstadt, 2015). In the aftermath of these attacks, President Clinton issued Presidential Decision Directive 39 (PDD-39) to further

FIGURE 1-4 A decontamination exercise on May 30, 1998 tests military and civilian agencies' ability to respond to a terrorist attack involving the release of sarin nerve agent. *US Air Force photo by SSgt. Renee Sitler.*

define the US approach to the terrorist use of weapons of mass destruction. This directive placed in context the role of public health and medical preparedness and response. "Crisis management" is described as principally a law enforcement function consisting of actions taken to prevent the occurrence of terrorist attacks. "Consequence management" denotes measures to protect public health and safety, restore essential government services, and deliver emergency aid to governments, businesses, and individuals affected by the consequences of terrorism.

Public Health Response to Terrorism

Congressional reaction to these terrorist threats included passage of the Defense Against Weapons of Mass Destruction Act of 1996. This act provided funding and guidance for the Secretary of Defense to "…assist the Secretary of Health and Human Services in the establishment of metropolitan emergency medical response teams (commonly referred to as 'Metropolitan Medical Strike Force Teams') to provide medical services that are necessary or potentially necessary by reason of a use or threatened use of a weapon of mass destruction" (USC, 1996). The following year, the Nunn–Lugar–Domenici Amendment to the National Defense Authorization Act for FY 1997 ratified funding for "Metropolitan Medical Strike Teams," which evolved into the Metropolitan Medical Response System (MMRS). The MMRS was a milestone in US public health and healthcare system preparedness. The threat of weapons of mass destruction prompted new planning for public health emergencies and established relationships between various agencies and stakeholders which continue today.

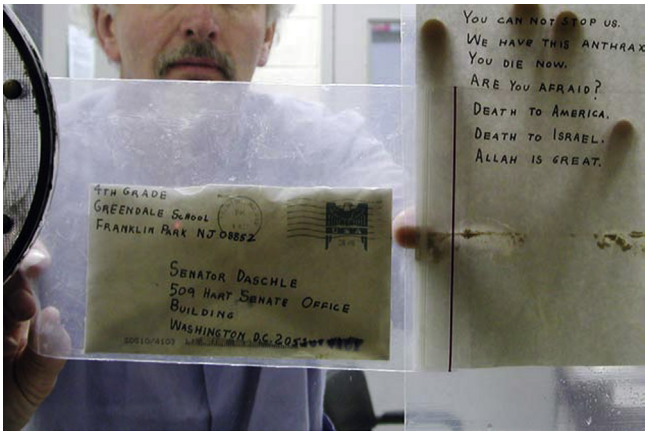

FIGURE 1-5 "A U.S. Army scientist stands near the letters used in the 2001 anthrax attacks. *Photo courtesy of the Federal Bureau of Investigation.*

Five years after the launch of the MMRS, terrorists carried out the infamous September 11 attacks. On a bright September morning in the fall of 2001, four aircraft were hijacked. Two were piloted into direct hits on the World Trade Center Twin Towers in New York City, resulting in the collapse of both buildings, one was flown into the Pentagon in Washington, D.C., and one crashed in a field in Pennsylvania when passengers fought back to avoid having the plane reach another prominent target. Less than two weeks after these terrorist attacks, several letters containing live *B. anthracis* (anthrax) spores were mailed to US media outlets. Two more such letters were subsequently mailed to two US senators. One of these letters can be seen in Fig. 1-5. Twenty-two people became ill after being exposed to the spores carried by those letters, and five died (Johnston, 2005).

The 2001 attacks ushered in a new era for public health and healthcare system preparedness. In addition to a federal funding boost for overall infrastructure in the decade following the 2001 attacks, a new public health mission emerged. Prior to this time, the terrorism response role of public health agencies was to assess the acute and long-term physical and mental health impact and recommend ways to mitigate those impacts in the future (Mellonee et al., 1996; Quenemoen et al., 1996). However, the growing threat of bioterrorism generated new partnerships with law enforcement, emergency management, and other key stakeholders (Butler et al., 2002). It also placed public health in a primary role of bioterrorism consequence management.

> *Our best approach is to strengthen the infrastructure that is so important to detecting and responding to a disease, and that is the public health and medical infrastructure. We need better surveillance, better laboratories, better protection.*
>
> *Henderson, D.A., MD, Professor and Dean Emeritus at the Johns Hopkins Bloomberg School of Public Health.*

In the months following the 2001 attacks, the US Congress passed the Public Health Security and Bioterrorism Preparedness and Response Act of 2002. The act resulted in a significant infusion of public health infrastructure funding at every level of government. Subtitle C of the act, "Improving State, Local, and Hospital Preparedness for and Response to Bioterrorism and Other Public Health Emergencies," required the Secretary of Health and Human Services to establish new preparedness grants or cooperative agreements (USC, 2002). Two five-year cooperative agreement programs were established: the Centers for Disease Control and Prevention's Public Health Preparedness and Response for Bioterrorism Program and the Health Resources and Services Administration's (HRSA) National Bioterrorism Hospital Preparedness Program. Both programs required specific activities designed to build public health and healthcare system preparedness and capacity.

The CDC Cooperative Agreement on Public Health Preparedness and Response for Bioterrorism incorporated a broad set of activities, including but not limited to:

1. Coordinating state and local planning for responding to bioterrorism and other public health emergencies.
2. Training public health and healthcare personnel.
3. Conducting exercises to test the capability and timeliness of public health emergency response activities.
4. Purchasing or upgrading equipment, supplies, pharmaceuticals, or other priority countermeasures to enhance preparedness for and responses to bioterrorism or other public health emergencies.
5. Enhancing communication to the public of information about bioterrorism and other public health emergencies.
6. Improving surveillance, detection, and response activities to prepare for emergency response activities including biological threats or attacks.
7. Improving training or workforce development to enhance public health laboratories.
8. Developing, enhancing, coordinating, or improving participation in systems by which disease detection and information about biological attacks and other public health emergencies can be rapidly communicated.
9. Preparing a plan for triage and transport management in the event of bioterrorism or other public health emergencies.
10. Preparing and planning for contamination prevention efforts related to public health that can be implemented in the event of a bioterrorist attack.

The HRSA National Bioterrorism Hospital Preparedness Program was established to coordinate improved preparedness of hospitals, emergency medical services systems, and other healthcare facilities for bioterrorist attacks and other emergencies. The funding was provided to each state and sometimes allocated by states to individual hospitals. The priorities of the initial program included personal protection for healthcare workers and patients, including quarantine and decontamination; biological disaster drills, training, patient transfer, and communications; and medications and vaccine stockpile and distribution planning (GAO, 2004).

By 2005, the CDC cooperative agreement nomenclature had changed. The focus on bioterrorism diminished over time, and the cooperative agreement was renamed the Public Health Emergency Preparedness (PHEP) grant. Various approaches to grant coordination and expectations evolved. In 2004 there were "focus areas" such as preparedness planning and readiness assessment, surveillance and epidemiology capacity, laboratory capacity, etc., and 2005 introduced "CDC preparedness goals" such as prevent, detect/report, investigate, etc. Each goal had specific outcomes, required critical tasks, and measures. This approach continued to evolve for another five years until the introduction of the "Public Health Preparedness Capabilities and Healthcare Systems Capabilities: National Standards for State and Local Planning" in 2011.

Expansion to All-Hazards Preparedness

As 2006 approached, funding for the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 was nearing expiration. The lessons learned from the massive public health and medical response to Hurricane Katrina and the global spread of H5N1, avian influenza significantly influenced the new legislation. By December 2006, the PAHPA was passed by Congress and signed by the president. The act directed the Secretary of Health and Human Services to establish new preparedness and response programs and positions. Among them were the continuation of the PHEP program and the Hospital Preparedness Program (HPP). New accountability provisions were put in place, and a renewed emphasis was placed on at-risk populations. This included children, pregnant women, the elderly, individuals with physical or mental disabilities, those with limited English proficiency, and anyone needing additional response assistance (HHS, 2008). The focus of the preparedness programs was purposefully expanded beyond their original concentration on bioterrorism to an "all-hazards" approach. This expansion was not to suggest preparedness planning should include plans for everything. The approach promotes using risk assessments within each jurisdiction in order to build the right jurisdictional capabilities with enough flexibility to respond to "all-hazards" specific to that area.

Photos related to the two influential issues in 2006 public health preparedness legislation, Hurricane Katrina, and growing concerns about an H5N1 avian influenza pandemic, are shown in Figs. 1-6 and 1-7.

PAHPA also established a new senior position and office in the Department of Health and Human Services (HHS). The Assistant Secretary for Preparedness and Response (ASPR) serves as the federal response lead for public health emergencies and disasters that surpass the ability of local and state governments. In addition to establishing and maintaining federal public health emergency and medical operational capabilities, the ASPR coordinates medical countermeasures research, development, and procurement, as well as overseeing state and local grant programs, assuring an "all-hazards" approach to strengthen public health and healthcare system capabilities for responding to emergencies and disasters. The HPP was also moved from the HRSA to the Office of the ASPR.

FIGURE 1-6 Hurricane evacuees arrive at New Orleans Airport, September 1, 2005. *Photo by Michael Rieger, Federal Emergency Management Agency.*

FIGURE 1-7 Poultry farms were the focus of international H5N1 avian influenza concerns. *Photo courtesy of the United States Department of Agriculture.*

Our "all-hazards" preparedness involves a shared responsibility among our entire Department, our partners in the international community, the Federal, State, local, Tribal and Territorial governments, the private sector, and, ultimately, individuals and families. Additionally, before an event, government agencies at all levels work with the private sector to plan and exercise so they can be ready when a disaster occurs (USC, 2008).

Rear Admiral (Ret.) Craig Vanderwagen, W., MD, Assistant Secretary for Preparedness and Response (2006–09).

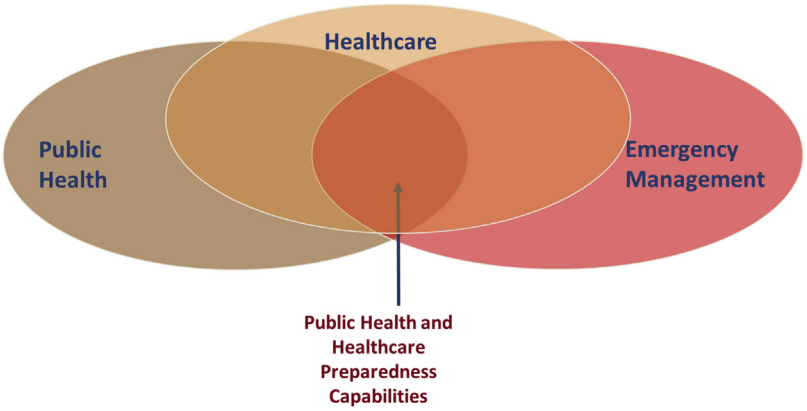

FIGURE 1-8 Public health and healthcare systems capabilities reside at the intersection of public health, healthcare, and emergency management.

PAHPA also introduced a set of benchmarks required for grant awardees. All state and local recipients were required to demonstrate the ability to successfully notify staff to manage a complex emergency; receive, stage, store, distribute, and dispense medical countermeasures during a public health emergency; and submit pandemic influenza plans (CDC, 2008). Although the benchmarks were clearly communicated and relatively easy to report on, they created a new challenge for these still-fledgling preparedness programs. Most public health programs have quantitative measures. For example, when an HIV program is introduced, there are numbers to track and targets to achieve, including increasing numbers of individuals being tested or receiving treatment. When a smoking cessation program is launched, the number of individuals who access cessation resources can be easily counted. However, with public health and healthcare system preparedness programs, measures of success and progress are much more difficult to characterize and report. The interrelations among public health, healthcare, and emergency management are illustrated in Fig. 1-8. These preparedness programs contribute to the systems and infrastructure needed to reduce the morbidity and mortality of public health emergencies and disasters. There are no simple numbers to quantitatively measure or illustrate how these programs reduce the impact of disasters on public health, but qualitatively, however, their value is definitive.

Introducing a Capabilities-Based Approach to Public Health Preparedness

Another preparedness milestone was reached in 2011. From the beginnings of PHEP and HPP nearly a decade earlier, there were challenges in organizing, prioritizing, and measuring preparedness activities. As a new five-year project period for the PHEP program was launched in 2011, the CDC introduced a capabilities-based approach. The approach was developed through an arduous, systematic process of reviewing all related federal guidance and strategies, a comprehensive literature review, and input from local, state, and federal stakeholders.

Table 1-1 The 15 Public Health Emergency Preparedness (PHEP) Capabilities and Eight Shared HealthCare Systems Preparedness Capabilities. Although There is Coordination Across All Capabilities, the PHEP Capabilities That are not Shared With HealthCare are the Specific Responsibilities of Public Health

	Public Health Preparedness Capabilities	HealthCare Preparedness Capabilities
1	Community preparedness	Healthcare systems preparedness
2	Community recovery	Healthcare systems recovery
3	Emergency operations coordination	Emergency operations coordination
4	Emergency public information and warning	
5	Fatality management	Fatality management
6	Information sharing	Information sharing
7	Mass care	
8	Medical countermeasures dispensing	
9	Medical material management and distribution	
10	Medical surge	Medical surge
11	Nonpharmaceutical interventions	
12	Public health Laboratory testing	
13	Public health surveillance and epidemiological investigation	
14	Responder health and safety	Responder health and safety
15	Volunteer management	Volunteer management

The result was a new national standard for public health preparedness, comprising 15 capabilities. In 2012, the ASPR Hospital Preparedness Program released the Healthcare Preparedness Capabilities. The eight healthcare preparedness capabilities are shared and aligned with the public health preparedness capabilities (Table 1-1). These 15 public health preparedness capabilities and eight capabilities shared with healthcare provided a vastly improved way of understanding the nexus among public health, healthcare, and emergency management. Efforts continue to align preparedness grant activities and more closely coordinate the preparedness efforts of public health and healthcare. An in-depth review of the capabilities-based approach to development, implementation, and benefits is provided in chapter: Public Health Preparedness Capabilities.

> *In the past, there have been many competing priorities and it's led to some difficulty in planning…we wanted to better define that and give a much better way for state and local public health to plan their activities and prioritize their investments.*
>
> *Christine Kosmos, R.N., BSN, MS, Division Director, Division of State and Local Readiness, CDC (2011).*

Preparedness Policy Development and Partnerships

In 2013, the Pandemic and All Hazards Preparedness Reauthorization Act (PAHPRA) was approved by Congress and signed by the President. This renewed the original PAHPA

legislation, including sustaining the PHEP program and the HPP. It also provided more flexibility for state and local public health agencies to dedicate staff from other federally funded programs to assist during public health emergencies. Previous restrictions precluded staff of categorical programs such as HIV and tuberculosis from assisting during an emergency, as they were funded through non-preparedness federal programs. New provisions allowed those staff members to support responses to pandemics and other all-hazards emergencies. PAHPRA also continued funding the research and development of new medical countermeasures and reduced the barriers for pharmaceutical manufacturers to receive Food and Drug Administration approval to distribute new drugs or vaccines during public health emergencies.

> *The reauthorization is a recognition of the importance of investing in innovation and supporting communities in public health preparedness. The programs and flexibilities provided through the reauthorized law will help move preparedness forward for our country and ultimately help build communities that are more resilient when faced with disaster.*
>
> *Rear Admiral Nicole Lurie, M.D., MSPH, Assistant Secretary for Preparedness and Response (ASPR, 2013).*

While the PAHPA and PAHPRA legislation have provided the direction and authorized the funding, more details were worked out by HHS, which has been charged with carrying out the requirements of the legislation. The next step for HHS was the development of the National Health Security Strategy (NHSS) with an implementation plan. The 2015 NHSS Implementation Plan had five objectives (ASPR, 2015). In the plan, each objective includes operational context and priorities. The objectives include:

1. Build and sustain healthy, resilient communities.
2. Enhance the national capability to produce and effectively use both medical countermeasures and nonpharmaceutical interventions.
3. Ensure comprehensive health situational awareness to support decision-making before incidents and during response and recovery operations.
4. Enhance the integration and effectiveness of the public health, healthcare, and emergency management systems.
5. Strengthen global health security.

The objectives and priorities described in the NHSS Implementation Plan drive the focus of the programmatic requirements associated with PHEP and HPP funding.

While Acts of the US Congress like PAHPA and PAHPRA are accompanied by specific expectations, benchmarks, or performance measures, the president also places expectations on preparedness programs. This is typically done through presidential directives. One example is the Presidential Policy Directive (PPD) called PPD-8: National Preparedness. In 2011, the Obama administration issued PPD-8 with the stated intent

"…to galvanize action by the Federal Government, it is also aimed at facilitating an integrated, all-of-Nation, capabilities-based approach to preparedness" (DHS, 2011). It includes six essentials:

1. The National Preparedness Goal describing the desired end-state:
   "A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to and recover from the threats and hazards that pose the greatest risk."
2. The National Preparedness System describing how to reach the goal.
3. The National Preparedness Framework explaining how the system will be used to achieve prevention, protection, mitigation, response, and recovery.
4. The National Preparedness Report tracking progress toward the goal.
5. Federal Interagency Operational Plans describing how federal government activities will achieve the framework.
6. The ongoing national effort to build and sustain preparedness momentum through public engagement, federal initiatives, grants support, research and development. (*FEMA, 2015*)

Subsequent presidential administrations issue new presidential directives to replace or update PPD-8. There are other presidential policy options as well, including Homeland Security Presidential Directives and National Security Presidential Directives. President Obama's PPD-8 was a modification and reissuance of HSPD-8, which was issued by President Bush's administration. The title used for these directives, PPD versus HSPD, depends upon the interpretation of each administration.

There are a variety of organizations supporting and shepherding the US preparedness policy process. Some are essential nonprofit organizations representing specific agencies or professions. The two most engaged in national public health preparedness policy are ASTHO and NACCHO. The Association of State and Territorial Health Officials (ASTHO) represents senior state public health professionals and their counterparts in US territories such as Puerto Rico and Guam. The National Association of County and City Health Officials (NACCHO) carries out similar work on behalf of 2800 local health departments across the country. These organizations provide a voice for state and local governmental organizations that have limitations on their ability to advocate for their individual programs. They facilitate the gathering of input from state and local preparedness programs to inform the interpretation of legislation and presidential directives used to develop future policies. ASTHO and NACCHO also serve as catalysts for improvements and changes which are difficult to achieve within the bureaucracy of governmental organizations. Other organizations with a more specific functional focus include the Association for Public Health Laboratories (APHL) and the Council of State and Territorial Epidemiologists (CSTE). APHL promotes public health laboratories as key partners in public health emergency preparedness and response through the development of standardized guidelines, policies, planning guidance, training tools, and

exercise materials for the Laboratory Response Network, which serves as an integrated network of labs with standardized processes that can rapidly detect emerging infectious diseases and other biological or chemical threats. CSTE provides similar support by enhancing and supporting public health surveillance and epidemiological capacity. CSTE specifically addresses emerging infectious disease and disaster epidemiology by developing methods and training materials to enhance the ability of epidemiologists to detect, describe, and evaluate public health emergency threats. ASTHO, NACCHO, APHL, and CSTE represent key public health preparedness partners, but this list is not exhaustive. There are many more national, state, and local organizations promoting and supporting preparedness efforts at every level.

Summary

This chapter summarizes the development of public health and healthcare systems preparedness policy in the United States. Public health preparedness is a relatively new discipline which became well established shortly after the 2001 terrorist attacks against the United States and the subsequent distribution of anthrax-tainted letters. It includes crosscutting programs which orchestrate interdisciplinary preparedness planning, training, and exercising. Although federal, state, and local public health preparedness programs were initially built with a focus on bioterrorism, later events including the 2005 Hurricane Katrina response and 2006 avian influenza global threat resulted in an expanded, all-hazards approach.

> *You can't buy preparedness, you rent it.*
>
> *Jeff Hoogheem, Deputy Director, Health Emergency Preparedness & Response Section, Texas Department of State Health Services.*

Much has been accomplished (Table 1-2), and the journey toward public health preparedness is never fully achieved due to changing threats and infrastructure. The organization and measurement of public health preparedness efforts continues to evolve as preparedness budgets often decline. The future of these programs is dependent upon establishing good policy, increasing and enhancing coordination with partners and stakeholders, as well as stabilizing and sustaining funding. Unfortunately, the base PHEP and HPP preparedness program funding has decreased, resulting in the erosion of preparedness and response infrastructure. Periodic health emergencies or threats prompt one-time federal infusions of supplemental funding with the expectation of efficient responses. Funding increases of this nature occurred in response to the avian influenza threat in 2006, the H1N1 response in 2009–2010, and the Ebola response in 2015. This approach is tantamount to delaying investments in national defense until a war is declared. In order to be effective, public health infrastructure must be built and sustained in advance of threats and emergencies. Public health and healthcare systems preparedness are moral imperatives and national security issues for all governments.

Table 1-2 US Public Health Emergency and HealthCare Systems Preparedness Progress, 1999–2015

1999	2015
CDC did not fund states for public health emergency and healthcare systems preparedness.	After the 2001 attacks, the US Congress appropriated funding for CDC to provide to all states to improve their preparedness and response capabilities.
No standardized response structure for state of local public health or healthcare systems. Ineffective coordination with emergency management.	State and local governments have adopted a standardized incident command system (ICS) structure that integrates public health and healthcare system response into emergency management.
No organized approach to public health and medical preparedness activities.	Public health emergency preparedness and healthcare systems preparedness capabilities are used by all state and local jurisdictions to organize and prioritize preparedness activities.
No public health and medical emergency operations centers.	Most states and major cities have public health and medical emergency operations centers that provide effective coordination with emergency management.
No public health risk-based planning or concerted attention for vulnerable populations.	Public health risk-based planning is the norm. A variety of programs are established addressing vulnerable populations, including those with disabilities and functional needs.
Limited external hospital disaster planning coordination. Most hospital disaster planning and training focused internally with little external coordination.	Most hospital planning and training is coordinated across the community-wide healthcare systems through healthcare coalitions.
Few, if any, mental health considerations in emergency planning and response.	Mental health professionals incorporated into response planning. Dedicated staff to plan, train, and exercise disaster behavioral health response.
No national stockpile of medical supplies available for use in emergencies. Few states had written plans for receiving, distributing, and dispensing stockpiled assets.	All states have plans to receive, distribute, and dispense assets from the CDC's strategic national stockpile.
Response efforts had few integrated communications or unified command needed for a large-scale response.	Public health departments in every state have established relationships and have conducted exercises with emergency management and other stakeholders.
No secure system was available to share information about emerging health threats.	CDC's epidemic information exchange (Epi-X) provides a secure, web-based communication system for sharing of preliminary health surveillance information.
No requirements existed in the United States for licensing, registering, or identifying organizations working with select agents and toxins.	The United States issued select agent regulations to enhance oversight of the safety and security of select agents and toxins and minimize inherent risks.
CDC conducted all tests to detect and confirm the presence of biological threat agents such as anthrax.	More than 150 laboratories in the United States belong to CDC's laboratory response network and have the ability to test for biological agents.

Adapted from Khan, A.S., 2011. Public health preparedness and response in the USA since 9/11: a national health security imperative. Lancet 378, 953–956 and Raphael, M., 2014. The evolution of a public health agency. Association of State and Territorial Health Officials (ASTHO), Tenth Annual Directors of Public Health Preparedness (DPHP) Meeting, October 7–9, 2014, Washington, DC.

Websites

Association of Public Health Laboratories, Public Health Preparedness and Response. http://www.aphl.org/aphlprograms/preparedness-and-response/Pages/default.aspx.

Association of State and Territorial Health Officials (ASTHO), Preparedness Program. http://www.astho.org/Programs/Preparedness/.

Centers for Disease Control and Prevention (CDC), Emergency Preparedness and Response. http://emergency.cdc.gov/.

Council of State and Territorial Epidemiologists. http://www.cste.org/.

National Association of County and City Health Officials (NACCHO), Public Health Preparedness. http://www.naccho.org/topics/emergency/index.cfm.

Public Health Foundation, Public Health Preparedness and Response. http://www.phf.org/programs/preparednessresponse/Pages/Public_Health_Preparedness_and_Response.aspx.

U.S. Department of Health and Human Services, Assistant Secretary for Preparedness and Response (ASPR), Public Health Emergency. http://www.phe.gov/preparedness/pages/default.aspx.

World Health Organization (WHO), Public Health Preparedness. http://www.who.int/influenza/preparedness/en/.

References

Butler, J.C., Cohen, M.L., Friedman, C.R., Scripp, R.M., Watz, C.G., October 2002. Collaboration between public health and law enforcement: new paradigms and partnerships for bioterrorism planning and response. Emerg. Infect. Dis. 8 (10), 1157–1159. Available at: http://wwwnc.cdc.gov/eid/article/8/10/02-0400_article.

Centers for Disease Control and Prevention (CDC), 2008. PAHPA Requirements that Affect Budget Period 11 Funding Decisions. Available at: http://www.cdc.gov/phpr/documents/coopagreement-archive/fy2008/benchmarks.pdf.

Centers for Disease Control and Prevention (CDC), 2011. Introduction to the Public Health Preparedness Capabilities (101). Available at: https://www.youtube.com/watch?v=74YpjEnSYSs.

Centers for Disease Control and Prevention (CDC), 2013. Our History - Our Story. Available at: http://www.cdc.gov/about/history/ourstory.htm.

Duffy, J., 1992. The Sanitarians: A History of American Public Health. University of Illinois Press, Champaign.

Federal Emergency Management Agency (FEMA), 2015. Learn About Presidential Policy Directive-8. Available at: http://www.fema.gov/learn-about-presidential-policy-directive-8.

Fieldstadt, E., April 19, 2015. Hope and Serenity: Oklahoma City Bombing Remembered 20 Years Later. NBC News. Available at: http://www.nbcnews.com/news/us-news/oklahoma-city-bombing-remembered-20-years-later-n344306.

Institute of Medicine (IOM), 1988. The Future of Public Health. National Academies Press, Washington.

Johnston, W.R., 2005. Review of Fall 2001 Anthrax Bioattacks. Centers for Disease Control and Prevention. Last modified March 17, 2005. Available at: http://www.cdc.gov/niosh/nas/rdrp/appendices/chapter6/a6-45.pdf.

Jones, M.M., 2005. Protecting Public Health in New York City: 200 Years of Leadership. New York City Department of Health and Mental Hygiene, New York, NY. Available at: http://www.nyc.gov/html/doh/downloads/pdf/bicentennial/historical-booklet.pdf.

Khan, A.S., 2011. Public health preparedness and response in the USA since 9/11: a national health security imperative. Lancet 378, 953–956.

Mallonee, S., Shariat, S., Stennies, G., Waxweiller, R., Hogan, D., Jordan, F., 1996. Physical injuries and fatalities resulting from the Oklahoma City bombing. JAMA 276, 382–387.

Martin, J.W., Christopher, G.W., Eitzen, E.M., 2007. History of biological weapons: from poisoned darts to intentional epidemics. In: Dembek, Z.F. (Ed.), Medical Aspects of Biological Warfare, (Series: Textbooks of Military Medicine). The Borden Institute, Washington, DC, p. 4.

Quenemoen, L.E., Davis, Y.M., Malilay, J., Sinks, T., Noji, E.K., Klitzman, S., 1996. The World Trade Center bombing: injury prevention strategies for high-rise building fires. Disasters 20, 125–132.

Raphael, M., 2014. The evolution of a public health agency. In: Tenth Annual Directors of Public Health Preparedness (DPHP) Meeting. October 7–9, 2014. Washington, DC. Association of State and Territorial Health Officials (ASTHO).

Roosevelt, F.D., July 1, 1944. Statement of the President on Signing the Public Health Service Act. The American Presidency Project. Made available online by Gerhard Peters and John T. Woolley: http://www.presidency.ucsb.edu/ws/?pid=16528.

Rosen, G., 1958. A History of Public Health. M.D. Publications, Inc., New York.

Seto, Y., June 1 , 2001. The Sarin Gas Attack in Japan and the Related Forensic Investigation. Organisation for the Prohibition of Chemical Weapons (OPCW). Available at: https://www.opcw.org/news/article/the-sarin-gas-attack-in-japan-and-the-related-forensic-investigation/.

United States Department of Health and Human Services (HHS), August 2008. Pandemic and All-Hazards Preparedness Act Progress Report on the Implementation of Provisions Addressing At-Risk Individuals. Available at: www.phe.gov/Preparedness/legal/pahpa/Documents/pahpa-at-risk-report0901.pdf.

United States Department of Health and Human Services Assistant Secretary for Preparedness and Response (ASPR), 2013. Secretary Nicole Lurie Statement on the Pandemic and All Hazards Preparedness Reauthorization Act. Available at: http://www.hhs.gov/news/press/2013pres/03/20130313a.html.

United States Department of Health and Human Services Office of the Surgeon General (OSG), 2015. History of the Office of the Surgeon General. Available at: http://www.surgeongeneral.gov/about/history/.

United States Department of Health and Human Services Assistant Secretary for Preparedness and Response (ASPR), 2015. National Health Security Strategy and Implementation Plan. Available at: http://www.phe.gov/Preparedness/planning/authority/nhss/Documents/nhss-ip.pdf.

United States Department of Homeland Security (DHS), March 30, 2011. Presidential Policy Directive/PPD-8: National Preparedness. Available at: http://www.dhs.gov/presidential-policy-directive-8-national-preparedness.

United States General Accounting Office (GAO), 2004. HHS Bioterrorism Preparedness Programs: States Reported Progress but Fell Short of Program Goals for 2002. GAO-04–360R. Available at: http://www.gao.gov/assets/100/92454.pdf.

United States Congress (USC), 1996. Defense against Weapons of Mass Destruction Act of 1996. Public Law: 104–201 September 23, 1996. Title XIV Defense Against Weapons of Mass Destruction. Available at: http://fas.org/spp/starwars/congress/1996/pl104-201-xiv.htm.

United States Congress (USC), 2002. Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Public Law 107–188 June 12, 2002. Available at: http://www.gpo.gov/fdsys/pkg/PLAW-107publ188/pdf/PLAW-107publ188.pdf.

United States Congress (USC), 2008. Emerging Biological Threats and Public Health Preparedness: Getting beyond Getting Ready. House Select Committee on Homeland Security. Serial No. 110–131, July 22, 2008, 110–2 Field Hearing. Available at: http://www.gpo.gov/fdsys/pkg/CHRG-110hhrg46261/html/CHRG-110hhrg46261.htm.

United States Public Health Service (USPHS), 2015. America's Health Responders, History. Available at: http://www.usphs.gov/aboutus/history.aspx.

World Health Organization (WHO), 2015. History of WHO. Available at: http://www.who.int/about/history/en/.

2

Public Health Preparedness Capabilities

OBJECTIVES

- Define public health emergencies.
- Describe the relationship between public health and healthcare in the context of emergency preparedness and response activities.
- List the 10 essential services of public health and describe examples on how they are sustained or modified for emergency response.
- Explain how public health activities are incorporated into the four phases of emergency management.
- List the 15 public health preparedness capabilities and associated healthcare system preparedness capabilities.
- Explain how individual preparedness is motivated.
- Define the "battle rhythm" of a response.
- List key information sharing factors which should be considered in response planning.
- Define and describe the importance of functional needs support services (FNSS).
- Describe how epidemiology is used in preparedness and response activities.

Introduction: Be Prepared—The 2008 Pahuk Pride Tornado

"Be prepared" is the motto of the Boy Scouts of America. The organization's founder, Robert Baden Powell, selected the motto and emphasized through the principles and practices of the organization that preparing yourself requires you to think through situations in advance. Your own well-being and the well-being of others depend on how you think about, prepare for, and react to a variety of situations (BSA, 1998). This creed was a central theme of Pahuk Pride 2008, a national youth leadership training initiative from the Mid-America Council of the Boy Scouts of America. The June 2008 gathering at the Little Sioux Scout Ranch in Iowa was designed to cultivate young leaders of troop programs. Attendance required a recommendation from an applicant's scoutmaster, and a scout applying was acknowledging the desire and willingness to lead others.

Nearly 100 of these young men were spread across the camping area when an alert came over a weather radio with a warning that dangerous weather was threatening the area. The Boy Scouts were quickly rushed into shelters and took refuge under tables and furniture in the two facilities. One of the facilities took the brunt of the storm. Four young men died and over 40 were injured (Keen and Stone, 2008). Several of the surviving scouts

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were recognized for their bravery. In fact, the actions of all were laudable. Their faithfulness to their motto certainly saved the lives of many young men that day. The scouts and their leaders had an emergency plan and exercised it. They monitored a weather alert radio, and when alerted, stayed calm and took the right measures in seeking shelter. When the storm passed, these young men were prepared to triage and care for the injured. The actions taken by the Boy Scouts that day in Iowa stand as an excellent example of preparedness and provide insights into the concept of resiliency.

The word "resilience" is taken from the Latin word "resilire" and literally means to bounce back or rebound. The word has historically been used as a social psychology term to describe those who bounce back from adversity through elasticity of spirit (Claudel, 1965). The term has migrated to other disciplines such as ecology, where it refers to the movement of an organism from one stable domain to another through the influence of turbulence (Holling, 1973). "Resilience" has been used in the field of industrial safety to describe the ability of a worker to anticipate risk and make changes before harm occurs (Hollnagel et al., 2006). As it relates to preparedness, resilience is the ability to anticipate, prepare for, and recover from the physical and psychological challenges of man-made and natural disasters. Preparedness is the process, and resilience is the result. How well a community bounces back from the adversity of a disaster largely depends upon how well prepared they are to face it. A resilient individual will have a more resilient home. A resilient community comprises resilient homes. A nation becomes resilient one person, one family, one home, and one community at a time. An in-depth discussion on resilience follows in chapter Community Disaster Resilience.

Public health emergencies are multidimensional, dynamic events overwhelming existing public health and healthcare infrastructure and resulting in adverse community health effects. Large-scale unanticipated events can pose extraordinary challenges. This includes natural or man-made as well as accidental or intentional events, with acute or chronic health effects. Public health emergencies generate a variety of diverse outcomes. The September 11, 2001 terrorist attacks on America killed thousands on the day of the attacks, but the health impact on those present during the response and recovery has been felt for years and continues. Chronic respiratory illness among those excessively exposed to dust and debris during cleanup, and mental health issues for those exposed to the trauma of the attacks, are just two examples of the lasting public health impacts of the 9/11 attacks. In that regard, the public health impact was acute and intentional on the day the planes hit the World Trade Center but remains chronic for many exposed to the dust during the recovery. Sustaining the public's health through the life cycle of a disaster such as the 9/11 attack requires a variety of public health preparedness, response, and recovery capabilities, and profound resilience.

Public Health Preparedness Infrastructure

The public health preparedness infrastructure spans public and private agencies and requires the involvement and interaction of healthcare, mental health, social services,

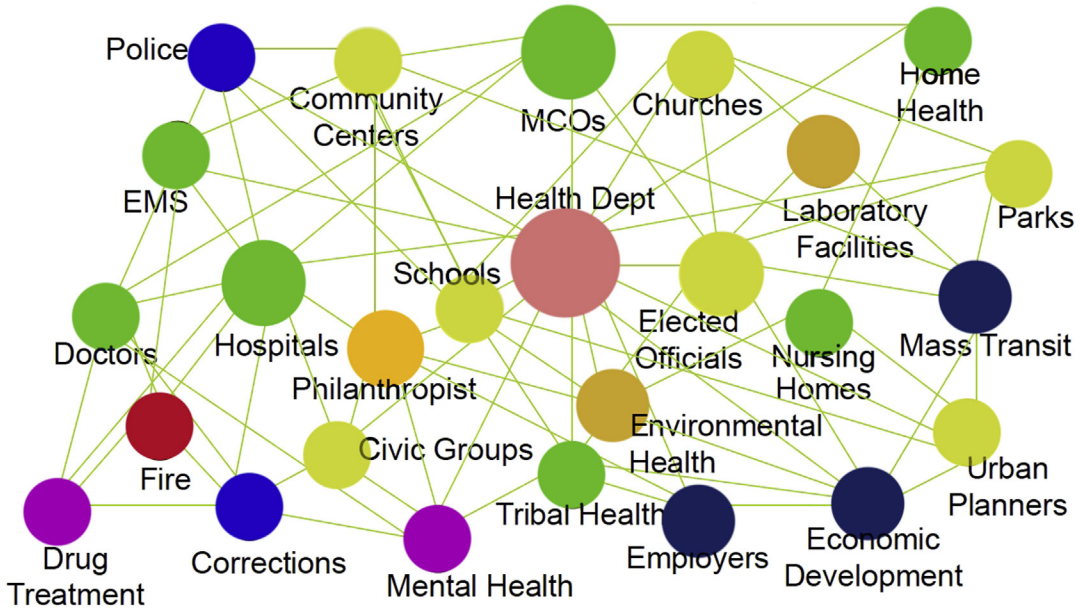

FIGURE 2-1 The public health system. *Image courtesy of the Centers for Disease Control and Prevention.*

education, elected officials, environmental, pharmaceutical, first responders, insurers, media, and many more. Preparedness activities are crosscutting and involve all public health programs and services. There are three core functions of public health: assessment, policy development, and assurance. Assessment includes continual evaluation of community health needs, investigation of risks, and analysis of health needs. Policy development is instituted, including advocating for resources, setting priorities, and developing plans and policies to address health needs. Assurance is the management of resources, implementation and evaluation of programs, and educating the public (IOM, 1988). These three core functions are met through the provision of 10 essential public health services. The 10 essential services summarize the activities all public health agencies and partners work to achieve though day-to-day public health program activities. Carrying out these essential services in the context of a public health emergency or disaster poses significant challenges. The public health system infrastructure is illustrated in Fig. 2-1.

Ten Essential Public Health Services:

1. Monitor health status to identify community health problems.
2. Diagnose and investigate health problems and health hazards in the community.
3. Inform, educate, and empower people about health issues.
4. Mobilize community partnerships to identify and solve health problems.

Continued

—cont'd

5. Develop policies and plans that support individual and community health efforts.
6. Enforce laws and regulations to protect health and ensure safety.
7. Link people to needed personal health services and assure the provision of healthcare when otherwise unavailable.
8. Assure a competent public health and personal healthcare workforce.
9. Evaluate effectiveness, accessibility, and quality of personal and population-based health services.
10. Research new insights and innovative solutions to health problems.

CDC (2014a).

In the 1970s, a US Comprehensive Emergency Management Model was first established. It comprises four phases: mitigation, preparedness, response, and recovery. *Mitigation* includes steps taken to anticipate and reduce the impact of a disaster. Building codes have been established in many regions that are likely to experience hurricanes and earthquakes. Enforcement of these codes mitigates the impact of a disaster by making structures less likely to suffer severe damage. One analogous public health mitigation measure is a vaccination program such as annual flu shots. *Preparedness* provides advanced planning and coordination to provide for a more effective response and recovery. The recurring threat of avian influenza spurs planning efforts which include antiviral medication and vaccine distribution plans which enhance overall public health preparedness. *Response* includes immediate actions taken during a current or imminent disaster. The health function of a response to a major disaster may involve mass triage, mass care, mass prophylaxis, or mass fatality management. *Recovery* includes activities sustained after the initial response, which begin restoring infrastructure including healthcare and public health services (Waugh, 2000). Recovery goes far beyond cleanup and infrastructure restoration. It includes the management of the far less visible chronic health effects and mental health outcomes of each disaster.

There is a complex interchange between the functions of emergency management and public health during each phase of the emergency management process. Each essential function of public health changes according to the phase of each emergency (See Fig. 2-2). For example, informing and educating the community about public health issues during mitigation and preparedness are very different messages than those shared during response and recovery. Developing plans supporting community health efforts becomes a dynamic process of activating appropriate resources and tasking responsible agencies in accordance with the established plans. Response activities are continually evaluated and adjusted to meet the needs of the affected population. There is no straightforward recipe for how these processes and resources are adjusted or how they mature through the life

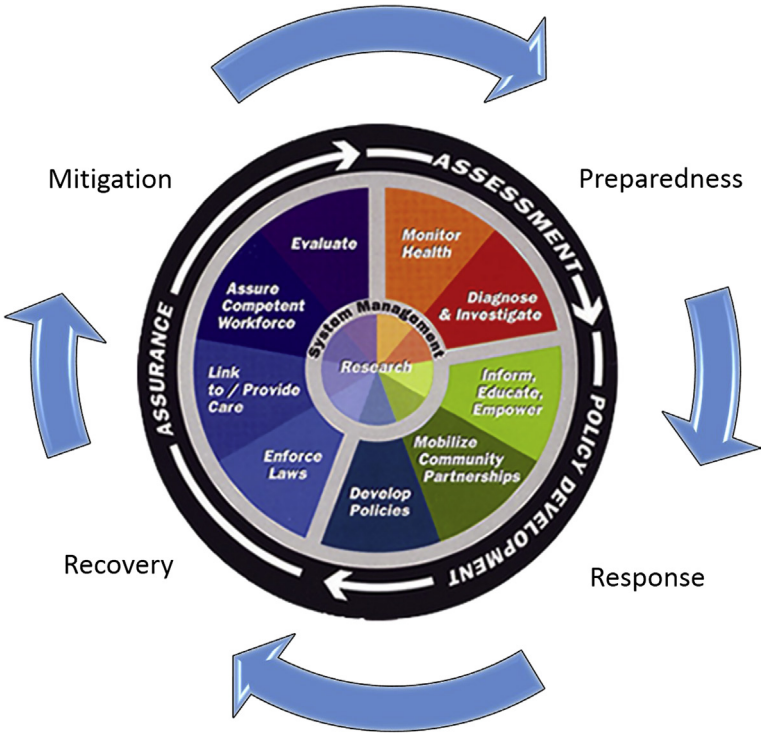

FIGURE 2-2 Essential public health services and the phases of emergency management (http://www.cdc.gov/phpr/capabilities/).

cycle of a disaster. Many public health agencies also experience difficulties maintaining essential services and assuring continuity of operations during a public health emergency or disaster. It is imperative for those serving in key emergency management and public health positions to understand the dynamic interaction of public health and emergency management throughout the life cycle of a disaster.

Public Health Preparedness Capabilities

The public health preparedness capabilities necessary to deliver public health and healthcare services in the United States throughout all four phases of emergency management have developed into a concise set of standards in recent years. The "capabilities approach" to public health emergency preparedness (PHEP) was introduced in 2011 to support better understanding, organization, and management of the array of public health preparedness capabilities and functions. This framework also simplifies strategic planning and allows for improved programmatic prioritization and measurement. The 2012 introduction of associated healthcare preparedness capabilities promotes alignment between public health and healthcare preparedness capabilities and activities.

In St. Louis, Missouri, the riverfront is dominated by the Gateway Arch. The Arch is a monument to the first American pioneers to venture west of the Mississippi River and settle the cities and states of the Western United States. It was completed in 1965 and is a weighted catenary curve which stands 630 ft (192 m) tall and 630 ft (192 m) wide at the base (Hicks, 1963). The term "catenary" comes from the Latin word for "chain." When a chain is held so the distance between each end is equal to the height, it is referred to as a catenary curve. When the curve is inverted as a solid shape, it is the strongest form of an arch (Yates, 1952). In other words, if the legs are either pulled further apart or pushed closer together, it will become a weaker structure.

There is a similar dynamic with public health and healthcare systems preparedness. There are close associations between the two. For example, an effective public health vaccination program can reduce patient surge across the healthcare system during a severe flu outbreak or pandemic. Effective management of a medical surge can reduce community anxiety, contribute to resilience, and reduce psychological symptoms and conditions resulting from a disaster. Public health and healthcare are inextricably connected. Trauma care is not provided at a local health department, and mass vaccination campaigns are not carried out at hospital emergency departments. Using public health and healthcare as the two legs of a catenary curve, these two infrastructures work together in varying degrees on shared capabilities but cannot be too close together or too far apart without both becoming weaker. Balancing the coordination of shared capabilities is a dynamic process, as public health and healthcare capabilities are distinct and separate. Fig. 2-3 displays the separate construction of the legs of the Gateway Arch. Fig. 2-4 provides sample programs of the healthcare system on the left leg and public health programs on the right. The capstone of the example is Emergency Support Function 8 (ESF-8), Public Health and Medical Services, coordination under the US National Response Framework.

FIGURE 2-3 Construction of the Gateway Arch. Each leg was built separately and connected at the top. *Image courtesy of the Missouri State Archives.*

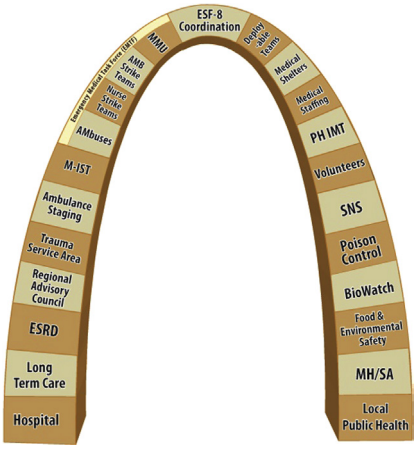

FIGURE 2-4 Illustration of healthcare preparedness programs (left leg) and public health preparedness programs (right leg) with the coordination of the two as the capstone. *Illustration courtesy of Stephanie Hoogheem.*

The 15 PHEP capabilities and 8 corresponding healthcare systems capabilities may be displayed in various ways to increase insight and understanding. The first is through the use of domains (Table 2-1). There are six domains which capture the 15 capabilities (CDC, 2011). (1) Biosurveillance is one of these domains, and includes epidemiological surveillance/investigation and laboratory testing. These activities are closely aligned with each other, and either can serve as a trigger for the other. Both capabilities also work in tandem during a public health emergency to detect emerging threats and characterize populations at risk and effective intervention strategies. (2) Resilience for communities and healthcare systems depends upon preparedness and recovery activities and requires engagement with, and involvement from, an array of public and private stakeholders. Response is captured in the other five domains. (3) Countermeasures and mitigation include effective management of pharmaceutical interventions which are dependent upon distribution and dispensing processes; nonpharmaceutical interventions (NPIs), including both governmental actions such as isolation and quarantine, and the promotion of public actions such as handwashing and avoiding congregate settings. Effective mitigation activities are also dependent upon the safety and health of responders. (4) Incident management is accomplished through emergency operations coordination carried out within a standardized incident command structure. (5) Information management includes external communication with the public to share emergency information and warnings. It also includes information sharing across a variety of disciplines and jurisdictions. (6) Surge management includes managing a surge of people needing basic support such as sheltering; a surge of patients needing immediate care; a surge of volunteers needing direction and control; or a surge of fatalities overwhelming local infrastructure. Reviewing the capabilities in the context of the six domains highlights their dynamic nature and overlap.

The public health preparedness capabilities are also listed side by side to highlight the eight shared healthcare preparedness capabilities (Table 2-2). The public health capabilities are detailed in the benchmark document, *Public Health Preparedness Capabilities: National Standards for State and Local Planning* (March 2011). In this invaluable reference,

Table 2-1 Public Health and HealthCare Systems Preparedness Capabilities by Six Domains

Biosurveillance
- Public health laboratory Testing
- Public health surveillance and epidemiological investigation

Community/healthcare systems resilience
- Community/healthcare preparedness
- Community/healthcare recovery

Countermeasures and mitigation
- Medical countermeasure dispensing
- Medical materiel management and distribution
- Nonpharmaceutical interventions
- Responder safety and health

Incident management
- Emergency operations coordination

Information management
- Emergency public information and warning
- Information sharing

Surge management
- Fatality management
- Mass care
- Medical surge
- Volunteer management

Table 2-2 Public Health and Healthcare Preparedness Shared Capabilities Listing with Tier 1 (T1) and Tier 2 (T2) Designations

Public Health Preparedness Capabilities		Healthcare Preparedness Capabilities	
1 (T1)	Community preparedness	1 (T1)	Healthcare systems preparedness
2 (T2)	Community recovery	2 (T2)	Healthcare system recovery, function 1
		2 (T1)	Healthcare system recovery, function 2 (continuity of operations)
3 (T1)	Emergency operations coordination	3 (T1)	Emergency operations coordination
4 (T1)	Emergency public information and warning		
5 (T2)	Fatality management	5 (T2)	Fatality management
6 (T1)	Information sharing	6 (T1)	Information sharing
7 (T2)	Mass care		
8 (T1)	Medical countermeasures dispensing		
9 (T1)	Medical material management and distribution		
10 (T2)	Medical surge	10 (T1)	Medical surge
11 (T2)	Nonpharmaceutical interventions		
12 (T1)	Public health Laboratory testing		
13 (T1)	Public health surveillance and epidemiological investigation		
14 (T1)	Responder health and safety	14 (T2)	Responder health and safety
15 (T2)	Volunteer management	15 (T2)	Volunteer management

the preparedness capabilities are defined and include a listing of three to six functions required to attain each capability. Detailed descriptions of tasks comprising each function are included, as well as performance measures and descriptions of resources needed to successfully perform each function. Combined with the companion guidance, *Healthcare Preparedness Capabilities: National Guidance for Healthcare System Preparedness* (January 2012), these comprehensive references set standards for the developing field of public health and healthcare systems preparedness—links are provided in the references at the end of this chapter. The focus of this text is on public health preparedness, and each capability described in this chapter will include a brief explanation of the capability with examples of promising practices. Healthcare systems preparedness capabilities are equally important and merit further discussion, but are not incorporated into this text.

Within each state and local PHEP program, capabilities prioritization should include jurisdictional risk assessment results and the capability tiers. Jurisdictional risk assessments identify the most likely and/or most impactful public health threats. Capabilities must be developed with consideration of those specific jurisdictional threats. In addition, the PHEP and HPP programs have developed a tiered capabilities strategy. Preparedness program budget reductions necessitate that resources are focused on foundational capabilities. Tier 1 capabilities are considered most essential for the program but not to the exclusion of Tier 2 capabilities. The tiers are intended to emphasize programmatic areas in need of priority sustainment and focus. Although all shared PHEP and HPP capabilities must be coordinated between the two programs, three of the six Tier 2 PHEP capabilities

require closer collaboration for sustainment, including fatality management, medical surge, and volunteer management. The other three Tier 2 PHEP capabilities, NPI, community recovery, and mass care, should be sustained but not necessarily receive the same attention and resources as the Tier 1 capabilities.

Public Health Preparedness Capabilities Summary

Capability 1: Community Preparedness

The community preparedness capability spans across all public and private sector preparedness activities and is rooted in building and maintaining partnerships. Activities are guided by a jurisdictional risk assessment which includes identifying the likelihood of specific hazards and threats. It is also important to define vulnerable populations which include those with chronic health conditions, language barriers, functional and access needs, and other susceptibility characteristics. Based upon the risk assessments, partnerships are established and sustained. This includes public sector partnerships with response agencies and officials. It also includes engaging private sector businesses and community groups. This engagement ranges from general awareness campaigns to preparedness planning, training, and exercises. The community preparedness capability and functions are shown in Fig. 2-5.

FIGURE 2-5 Community preparedness capability and functions.

Function 1: Determine risks to the health of the jurisdiction.
Function 2: Build community partnerships to support health preparedness.
Function 3: Engage with community organizations to foster public health, medical, and mental/behavioral health social networks.
Function 4: Coordinate training or guidance to ensure community engagement in preparedness efforts.
CDC (2011).

Community Preparedness Capability Example: Motivating Individual Preparedness

The requisite steps for becoming a prepared individual include the acknowledgment of risk and responsibility, staying informed, making a plan, and getting involved. Individual risks vary according to where people live, work, or travel, so it is important for everyone

to consider the full range of potential health threats possibly affecting them, their family, friends, and neighbors. In the United States, most major disaster risks are well understood in each geographical region. The Atlantic and Gulf Coast areas are susceptible to hurricanes. The West Coast and Midwest have major fault lines where earthquakes may occur. Extreme weather events affect the entire nation, but tornados are more likely in the Midwest and blizzards are more likely in the North. The threats of emerging infectious diseases and terrorism have no predictable geographic distribution and are considered threats everywhere. In spite of understanding the typical regional and local health emergency and disaster threats posed across the United States and around the world, most people fail to adequately prepare.

In efforts to prepare the public and minimize the health impact of disasters, the first question often asked is, "What should I be prepared for?" Worst case scenarios are sometimes used in an effort to motivate preparedness activities. Many people have a difficult time comprehending extreme threats such as a nuclear detonation or an anthrax attack. If preparedness is framed with extreme scenarios, some dismiss the threats and take no action toward preparedness. This dismissive attitude prevails even among many public health and healthcare professionals. Although disasters consistently occur, there are periodic extreme disasters impacting the health and safety of hundreds or thousands of people. The problem is not an inability to convince residents of hazards common to their geographic region. The challenge is in convincing them that they may be directly affected, the disaster may be far from typical, and they can carry out some relatively simple steps to prepare. Individuals also need to understand that there are unlikely but potentially large disaster threats for their region. The impact of these disasters can be greatly diminished by simple individual preparedness measures. An example of this, the California Community Emergency Response Team (CERT) volunteer training program, is illustrated in Fig. 2-6.

FIGURE 2-6 California Community Emergency Response Team (CERT) volunteers participating in a disaster exercise. *Image courtesy of the California National Guard.*

The barriers to individual preparedness are still not well understood, but emerging research offers some insight into why some take actions to prepare while others do not. The type of regional disaster threats plays an important role in the perception of risk and subsequent actions toward preparedness. Previous individual experience with disasters and gender plays significant roles as well (Ho et al., 2008). In addition to risk perception, social influences and access to resources influence the preparedness actions of individuals. Overcoming these barriers to stimulate personal preparedness and appropriate public response requires an adapted and comprehensive communication initiative (Riad et al., 1999). Effective public motivation requires comprehensive risk communication. There are several "cardinal rules" which preparedness and response agencies and organizations must keep in mind:

- Accept and involve the public as a legitimate partner.
- Plan carefully and evaluate your efforts.
- Listen to the public's specific concerns.
- Be honest, frank, and open.
- Coordinate and collaborate with other credible sources.
- Meet the needs of the media.
- Speak clearly and with compassion.
  Covello and Allen (1988).

These rules were developed for use during response and recovery but are not exclusively for crisis communication. The same principles can be adapted to better communicate preparedness before crises occur. The public must be included in both individual and community preparedness activities. Programs must be carefully tailored for each community and involve the public. A two-way preparedness dialogue must be established, and credible, competent information sources should be used to deliver key preparedness messages. These messages must be simple. For example, in the United States, the Federal Emergency Management Agency promotes a four-step process for individual and family preparedness:

1. Be informed: Know what to do before during, and after an emergency.
2. Make a plan: Planning should include communication, special considerations for children, the elderly, and those with functional and access needs. It also includes caring for pets.
3. Build a kit: A basic disaster supply kit and "go bag" should be prepared and maintained.
4. Get involved: Explore the preparedness activities in the community and look for opportunities to volunteer for preparedness and future response activities.
   FEMA (2015).

The "Ready.gov" program also summarizes the first three for further simplification and remembrance: "Prepare, Plan, Stay Informed." The program includes a variety of resources to support these basic preparedness activities. Videos and publications are available on the website or can be ordered for free by mail, e-mail, fax, or over the phone.

Capability 2: Community Recovery

The community recovery capability includes all public and private sector recovery activities, and like community preparedness, it is rooted in building and maintaining partnerships. Recovery includes many of the same stakeholders as preparedness but for major disasters is expanded to include additional recovery support from both inside and outside the community. In fact, preparedness and recovery activities are sometimes indistinguishable, since postincident public health medical and mental/behavioral health services and systems recovery planning is part of preparedness and mitigation—the lessons learned from response and recovery are incorporated into future preparedness and mitigation activities during the recovery process. The community recovery capability is outlined in Fig. 2-7.

Recovery begins with an assessment of postincident public health, medical and mental/behavioral infrastructure to determine what gaps in assets, facilities and resources were created by the disaster and what resources remain available for postincident recovery. Coordination of public and private recovery partners is a complex challenge. There may be a surge of volunteers and other resources immediately following a disaster. In fact, one of the greatest recovery challenges is spontaneous volunteer and donations management. Recovery coordination includes businesses, faith-based, and other nongovernmental organizations. Organization of resources and collaboration of the stakeholders is orchestrated to return public health, medical, and mental/behavioral to preincident levels and/or expand capacity as the needs demand and as resources allow.

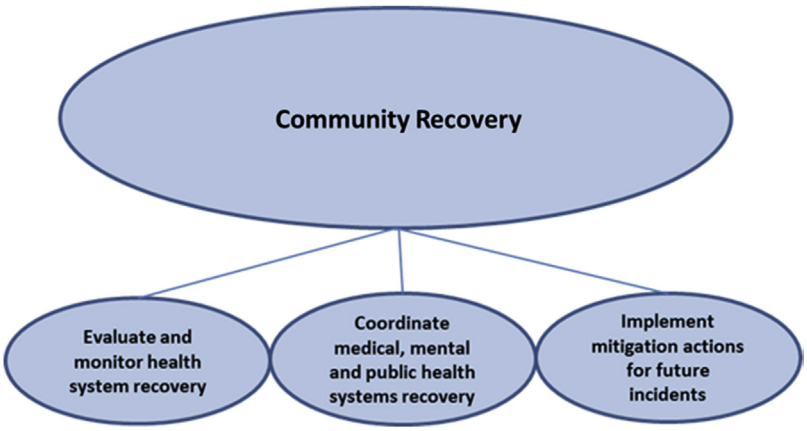

FIGURE 2–7 Community recovery capability and functions.

Function 1: Identify and monitor public health, medical and mental/behavioral health system recovery needs.
Function 2: Coordinate community public health, medical and mental/behavioral health system recovery operations.
Function 3: Implement corrective actions to mitigate damages from future incidents.
CDC (2011).

Community Recovery Capability Example: Earthquake Recovery in Chinatown

A group of healthcare agencies formed a nonprofit agency in 1985 to improve the health and well-being of the San Francisco Chinese community." The group is called NICOS Chinese Health Coalition, which stands for North East Medical Services; IPA (Chinese Community HealthCare Association); Chinese Hospital; On-Lok Senior Health Services; and Self-Help for the Elderly. Following the 1989 Loma Prieta earthquake, the Chinatown Disaster Preparedness Committee was formed. Their challenge was unique. Chinatown is the second-most densely populated neighborhood in the United States, with limited English-speaking proficiency in three-quarters of the population. The neighborhood is located in a region where seismic activity is common, and much of the housing infrastructure has not been retrofitted for earthquakes. About 20% of the population is over 65 years of age. Many have medication dependence, and others have limited mobility (CIDRAP, 2015a).

With funding from the San Francisco Department of Emergency Management, the Chinatown Disaster Preparedness Committee created the San Francisco Chinatown Disaster Response Plan. The plan is simple and provides full translations of English and Chinese. Planning includes mapping key neighborhood locations including the command center and treatment locations for the injured. Diagrams are included in the plan explaining how communications will be coordinated across Chinatown following a disaster (NICOS, 2007). Roles and responsibilities for neighborhood positions are defined, including:

- community disaster coordinator
- public information officer
- liaison officer
- community operations leader
- community planning leader
- community logistics leader
- administration and finance leader
- communications officer
- block captain
- neighborhood emergency response team
- runner.

NICOS (2007).

The efforts of the NICOS Chinese Health Coalition and Chinatown Disaster Preparedness Committee are commendable and will clearly enhance Chinatown's community resilience and future recovery operations. In addition to the plan, a variety of bilingual preparedness materials have been developed and distributed throughout Chinatown. Residents and community organizations have been engaged, and recovery from a major earthquake or any other major disaster will be led by citizens and grassroots community organizations.

Capability 3: Emergency Operations Coordination

Emergency operations coordination begins with establishing a location for an emergency operations center (EOC) and a backup location to assure continuity of operations. EOC location considerations must include the hazards and vulnerabilities that pose risks to operational sustainment. In the event the primary location is not available or accessible, an alternate location must be established in advance. For government organizations, a backup EOC may be established at another governmental facility. A nongovernmental facility can also be used with advanced planning and coordination, including establishing a contingency contract or memorandum of agreement (MOA). In either case, consideration should be given to the following: Is the EOC in a facility which has structural integrity, can be quickly secured, is accessible 24 hours per day, has backup power available, has sufficient infrastructure to support communications, and has sufficient space to scale up operations as needed?

Activation triggers and procedures must be well planned and exercised. The preliminary assessment for activation is accomplished in conjunction with jurisdictional elected officials, emergency management, public health leaders and subject matter experts. Activation can range from a small virtual activation supporting small-scale operations during business hours to full-scale, 24 hours per day and 7 days per week. The specific incident management structure is tailored for each event or incident based on the type of public health, medical, and mental/behavioral health support anticipated. Flexible and scalable procedures must be in place for communication, coordinating response activities, resource requests, memoranda of understanding (MOUs) and/or MOAs, and other operational procedures. Fig. 2-8 shows a typical exercise, preparation for a hurricane, at the State Medical Operations Center in Texas, and Fig. 2-9 displays the emergency operations capability and functions.

An incident action plan (IAP) is used to document the goals of an operational period. In the IAP, objectives are defined as well as the tactics for achieving the goals. The IAP is continually updated as operational challenges evolve and includes information such as:

- incident goals (what the response system intends to accomplish (or achieve) by the end of the response)
- operational period objectives (major areas to be addressed in the specified operational period in order to achieve the goals or control objectives)
- response strategies (priorities and the general approach to accomplish the objectives)
- response tactics (methods developed by the operations branch to achieve the objectives)

FIGURE 2-8 The Texas State Medical Operations Center during a 2015 hurricane exercise.

- organization list with the incident command structure (ICS) chart indicating primary roles and relationships
- assignment list including specific tasks
- critical situation updates and assessments
- composite resource status updates
- health and safety plan (to prevent responder injury or illness)
- communications plan (how functional areas will exchange information)
- logistics plan (eg, procedures to support the Operations Branch with equipment, supplies, etc.)
- responder medical plan (providing direction to care for responders)
- incident map (ie, map of incident area)
- additional component plans as indicated by the incident
  HHS (2007).

As the event or incident progresses, the challenges of emergency operations include maintaining the operational tempo, situational awareness, tracking deployed resources, and planning demobilization. The operational tempo is also sometimes referred to as the "battle rhythm," and includes recurring meetings, conference calls, and reporting. Maintaining the operational tempo during a shift change can be challenging, as outgoing EOC staff must brief the incoming shift on the current priorities and the status of current activities and tasks, while continuing to have a presence in meetings and on conference calls. Demobilization of deployed assets and the EOC requires advanced planning which should begin as soon as activation occurs. Once all assets are accounted for and documentation is compiled and organized, the after action review (AAR) process begins. AARs include a complete review of public health response operations to identify areas for improvement as well as promising practices to be sustained in future responses.

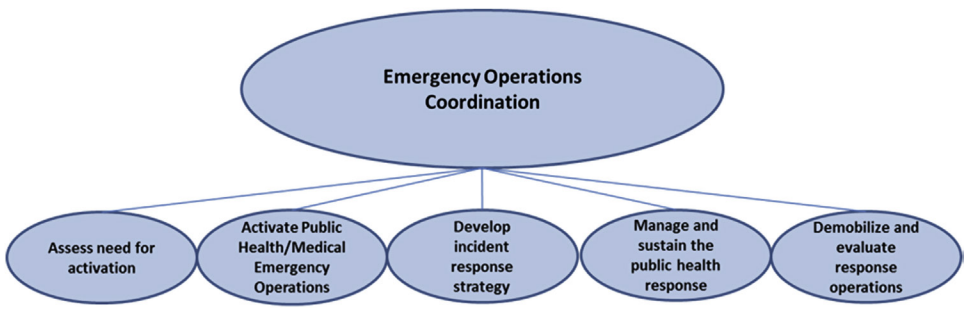

FIGURE 2-9 Emergency operations capability and functions.

Function 1: Conduct preliminary assessment to determine need for public health activation.
Function 2: Activate public health emergency operations.
Function 3: Develop incident response strategy.
Function 4: Manage and sustain the public health response.
Function 5: Demobilize and evaluate public health emergency operations.
CDC (2011).

Emergency Operations Capability Example: Cross-Border Collaboration for Chemical Antidotes

Some major events require extensive advanced emergency operations planning. Included among these events are high-profile international events such as the Olympic Games. The 2010 Winter Olympics was held in Vancouver, British Columbia. Planning for public health emergencies included cross-border coordination between the Washington State Department of Health (WSDOH) and the British Columbia Ministry of Health (BCMOH). Their cross-border emergency preparedness efforts included rapid deployment of chemical antidotes needed should there be a chemical terrorism attack involving organophosphates (nerve agents). The Centers for Disease Control and Prevention (CDC) has placed CHEMPACKs across the United States, which include atropine and pralidoxime chloride. The WSDOH worked closely with the BCMOH to establish plans for rapid transport of CHEMPACKs across their international border within 1 hour of an attack. Had there been a need for the antidotes, the notification processes and transportation arrangements were all preapproved and coordinated across multiple jurisdictions and an international border (CIDRAP, 2015b). This is an example of a successful emergency operations coordination effort. The barriers which would have been encountered were resolved in advance making the timely deployment of critical assets possible.

Capability 4: Emergency Public Information and Warning

Public health emergencies require the capability to rapidly and effectively share public information and warnings, and this capability is outlined in Fig. 2-10. This is distinct from the information sharing capability, which has an internal focus on response partner and stakeholder communications. The emergency public information and warning capability is externally focused public messaging and warnings. Prior to an incident, the processes and spokespersons must be identified. A public information officer (PIO) should be predesignated and trained on principles of crisis communication. Activation processes include preplanning the methods of communication and reporting locations. The PIO may work in a virtual activation from their regular workplace or, depending upon the size of the event or incident, may also have a seat in the EOC. All activated PIOs may also report to a joint information center where information and news releases are coordinated with PIOs representing other responding organizations. The PIOs monitor mass media and social media to identify rumors needing to be addressed in press conferences or news releases. PIOs can also establish two-way communication between public health and the public using call centers, social media, and other communication methods. Challenges PIOs face include reaching vulnerable populations, including those speaking other languages or who have limited access to television or social media.

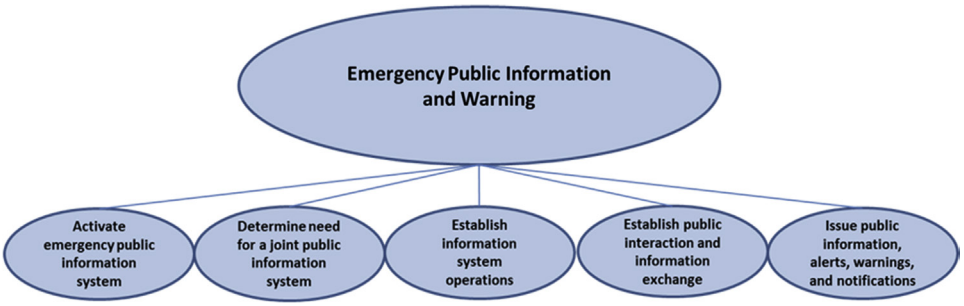

FIGURE 2-10 Emergency public information and warning capability and functions.

Function 1: Activate the emergency public information system.
Function 2: Determine the need for a joint public information system.
Function 3: Establish and participate in information system operations.
Function 4: Establish avenues for public interaction and information exchange.
Function 5: Issue public information, alerts, warnings, and notifications.
CDC (2011).

Emergency Public Information and Warning Example: Emergency Dark Websites

As growing numbers of people turn to the internet for news and information, it is important to have materials prepared in advance to post during an emergency. However, organizing and posting information on a Website takes time. Many private sector businesses face crisis situations requiring rapid public communication. This includes food, beverage, and pharmaceutical companies issuing emergency information on food or drug recalls. Rather than waiting until a crisis emerges, many companies develop "dark websites." These websites are predesigned for an emergency and not visible until they are turned on. The "dark Website" can replace a home page, be accessed by a link on a homepage, or be launched as a separate Website. This allows for rapid Website customization and launch based on the emergency situation. Some public health agencies have also begun creating dark sites.

Santa Clara County Public Health Department (SCCPHD) collaborated with Stanford University students and faculty to develop a dark site. This collaboration occurred in April 2009 after the SCCPHD Website crashed due to the volume of hits from individuals seeking information on the novel H1N1 virus. The volume of internet traffic on the site brought down both the SCCPHD site and the rest of the county's websites. The agency's PIO worked quickly with Stanford University and built a dark site using Google as the host. Building the dark site was accomplished within hours and a link was added on the nonfunctioning SCCPHD Website redirecting to the new dark site once it was activated (CIDRAP, 2015c). The use of dark sites provides important opportunities for preplanning web-based emergency public information and warnings.

Capability 5: Fatality Management

Public health agencies have varying levels of involvement with fatality management, depending upon the direction of the designated jurisdictional authority. In the United

States, this authority may be a medical examiner, coroner, sheriff, or justice of the peace. The determination of public health's response role must be described in planning documents and understood by responders prior to an emergency or disaster (this capability is illustrated in Fig. 2-11). In some regions, public health has an operational leadership role while in other areas the role of public health is marginalized. Roles and responsibilities should be detailed in mass fatality plans. Planning considerations include:

- fatality projections from a jurisdictional risk assessments
- rules and regulations of fatality management
- lines of authority over fatality management operations
- remains recovery, tracking, and transportation
- facilities for remains processing and storage
- equipment and supplies for remains recovery, transport, and storage
- morgue operations
- death care industry resources, including private sector resources for funerals, cremations, and burials
- MOUs and/or MOAs with key organizations and businesses within the jurisdiction, and as needed with surrounding jurisdictions
- family assistance center (FAC) operations and procedures for coordinating with the families of the deceased
- public communication and information

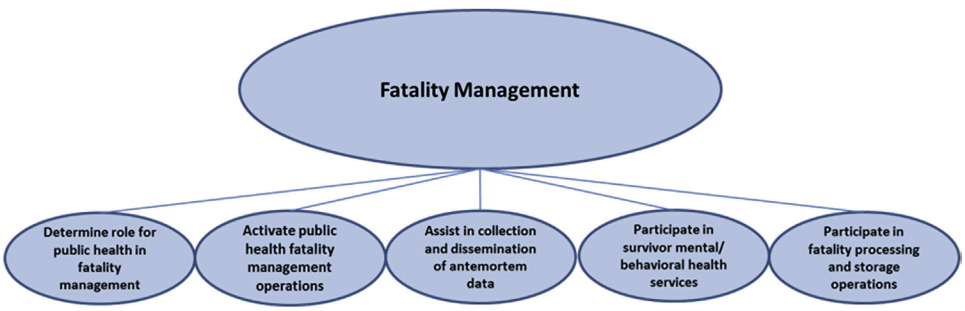

FIGURE 2-11 Fatality management capability and functions.

Function 1: Determine role for public health in fatality management.
Function 2: Activate public health fatality management operations.
Function 3: Assist in the collection and dissemination of ante mortem data.
Function 4: Participate in survivor mental/behavioral health services.
Function 5: Participate in fatality processing and storage operations.
CDC (2011).

Fatality Management Example: Public Health—Seattle & King County Mass Fatality and Family Assistance Operations Response Plan

Mass fatality planning poses many challenges for public health. Although the responsibility for mass fatality management plans falls to public health agencies, not all Medical

Examiners, Coroners, and others with jurisdictional authority on death issues consider these plans a priority. Public Health—Seattle & King County has a unique structure with inclusion of the King County Medical Examiner's Office (KCMEO) in Public Health. KCMEO partnered with planners from the Northwest Healthcare Response Network and met weekly for six months. The group produced a 40 page concept of operations document with 80 attachments including protocols, instructions, and templates. A separate group was convened to work on FAC planning. The FAC planning group included the same participants as the mass fatality planning but added subject matter experts from law enforcement, emergency management, community and human services, and the American Red Cross. The group met monthly for 8 months and developed a FAC concept of operations which also included protocols, instructions, and templates (Taylor et al., 2012). The two efforts became the basis for the Public Health-Seattle & King County Mass Fatality and Family Assistance Operations Response Plan. This plan serves as an example of exemplary planning and accomplishes the objectives posed in the opening section of the plan to:

- prepare the county for the management of a mass fatality incident
- outline operational areas and provide supporting guidelines and operational documents
- identify the roles and responsibilities of agencies and organizations likely to be involved
- specify the command and control structure, including activation of the plan
- describe the logistics operation and outline how to request resources
- outline the process to provide a private and secure place for families to gather and to receive information about the response and recovery
- outline the process for information sharing with hospitals to support family reunification with the injured
- specify the informational, psychological, spiritual, medical and logistical needs of families
- centralize and coordinate missing person inquiries
- outline the process for collecting ante mortem information on the missing or known deceased
- facilitate information exchange between the KCMEO and families
- provide death notifications and facilitate the processing of death certificates and the release of human remains for final disposition as needed
- protect families from the media and curiosity seekers.
  KCMEO (2015).

Capability 6: Information Sharing

Communication errors and omissions are consistent findings in AARs following disasters. In spite of continued efforts to improve it, information sharing always needs improvement.

The communication process begins with identifying all agencies and stakeholders who should receive information. This includes but is not limited to public health agencies, healthcare facilities, emergency management, elected officials, fire, law enforcement, EMS, and mental/behavioral health. Fig. 2-12 outlines the information sharing capability and functions. The type of data shared, how it is used, and who is allowed to receive and share the information varies. Some health information may only be shared with specific agencies under unique circumstances. Laws, regulations, and policies must be reviewed and understood by public health responders prior to an incident or event. In the United States, these include federal laws and guidance such as the Health Insurance Portability and Accountability Act, Office of the National Coordinator Health Information Technology Policy, HHS Information Management Policy as well as state laws and local policies. Sharing protected information during a crisis may require MOAs or MOUs which can be established in advance of an activation and response. Comprehensive emergency plans or standard operating guidelines should include information such as:

- processes and procedures for stakeholder communication
- access to electronic systems, with backup systems, capable of sharing data and alerts
- key sources of information including health alerts and fusion centers
- health information exchange protocols
- classified information exchange protocols
- encryption standards
- verification of trusted information sources
- message and report templates
- training requirements of those handling information

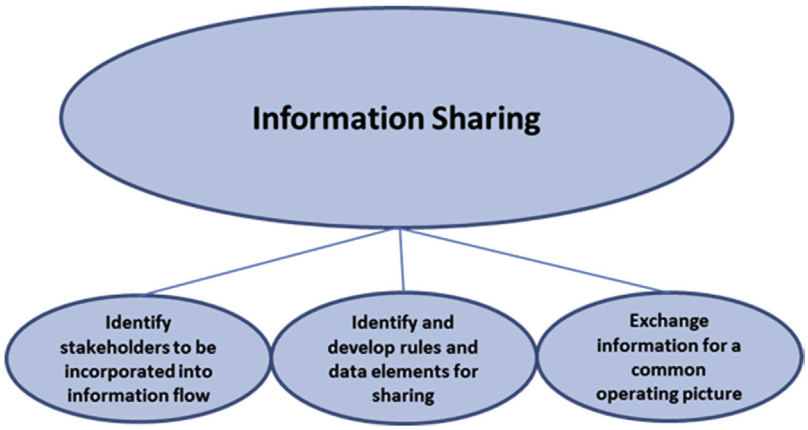

FIGURE 2-12 Information sharing capability and functions.

Function 1: Identify stakeholders to be incorporated into information flow.
Function 2: Identify and develop rules and data elements for sharing.
Function 3: Exchange information to determine a common operating picture.
CDC (2011).

Information Sharing Example: Denver Public Health HANDI (Handheld Automated Notification for Drugs and Immunizations) System

Public health response operations generate large volumes of critical data used for decision-making. When a vaccine exists for a novel influenza strain associated with a pandemic, mass vaccination clinics provide the most effective response strategy. Client information from these clinics has typically been captured on paper, increasing process time and resulting in longer wait times at vaccination clinics. The client information is then entered into an electronic database and shared with decision-makers. The paper approach slows throughput causing delays in providing vaccine to clients and mass vaccination clinic information to officials.

In order to address the delays of a paper-based system, Denver Public Health developed a tool for rapid data collection and standardization. A mobile application called HANDI (handheld automated notification for drugs and immunizations) was introduced to streamline three workstations.

Station 1—Registration: The magnetic strip on the back of the driver's license is scanned by swiping the card through a small accessory attached to a mobile device. The system captures key personal information from the license rather than having the individual fill out paper forms to be entered into an electronic database. The mobile application allows additional information to be entered manually as well. The application also generates a bar code associated with each individual's information. The barcode is printed and given to the patient.

Station 2—Interview: The patient presents the barcode to the interviewer. The scanned barcode links the individual's information to the interview form. Several screening questions are asked including the patient's history of allergies. Responses to the questions are captured electronically on the interviewer's mobile device.

Station 3—Documentation: The patient's barcode is scanned again prior to receiving the vaccination and the vaccine manufacturer, lot number, dosage and other key variables are entered. The final dataset uses HL7 messaging technology for near real-time information transfer to the state's immunization registry (McClung, 2012). Although the HANDI application was developed for mass vaccination clinics, it may also be modified for other medical countermeasure dispensing.

Health Level Seven International (HL7) is a nonprofit organization which developed health information standards to establish interoperability in electronic health information. "Level Seven" is a reference to the International Organization for Standardization seven-layer model. It is the application level of a communications model for open systems interconnection. HL7 provides enhanced security and interoperability of health information (HL7, 2015)

Capability 7: Mass Care

Mass care is the provision of public health, medical, and mental/behavioral health in congregate settings, and is summarized in Fig. 2-13. These activities are closely coordinated with emergency management, social support services and other agencies providing mass care in locations such as general population shelters. Key partners also include volunteer organizations active in disasters (VOADs), discussed more in Capability 15, Volunteer Management. Jurisdictional risk assessments are useful in advanced planning and can assist in anticipating community mass care needs. Some mass care roles of public health can be predetermined including health monitoring, sanitation, food and water safety, and environmental health and safety assessments. Clean, separate, safe pet accommodations must also be considered. Other public health mass care roles are unique to specific scenarios including mass decontamination operations following a radiological or chemical incident.

Public health can provide medical support to shelter operations for health assessments and basic care. Mental/behavioral health services can also be provided for psychological first aid and other initial measures, as well as referrals for more advanced support. Public health can also arrange for delivery of durable medical equipment (DME) for individuals who have left theirs behind when rapidly evacuating from their home during an emergency. DME may include wheelchairs, bariatric cots and equipment, continuous positive airway pressure machines, nebulizers, O_2 tanks, catheters, and blood glucose monitors. An array of prescription medications are also needed during shelter operations. Support for medication needs may include transport to a pharmacy for refills or storage and security of medications in a mass care operation. Some individuals, however, may be in immediate need of medications for diabetes, cardiovascular conditions, or respiratory illnesses and must have quick access to critical drugs. Public health should have MOUs, MOAs, or contingency contracts in place to rapidly provide needed pharmaceuticals and DME.

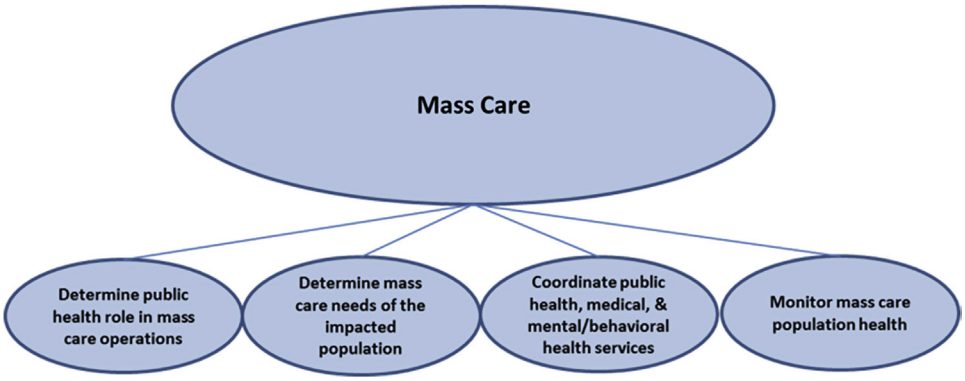

FIGURE 2-13 Mass care capability and functions.

Function 1: Determine public health role in mass care operations.
Function 2: Determine mass care needs of the impacted population.
Function 3: Coordinate public health, medical, and mental/behavioral health services.
Function 4: Monitor mass care population health.
CDC (2011).

Mass Care Example: Functional Needs Support Services (FNSS) Guidance

Functional needs support services (FNSS) have become a high priority in the United States. Although there have been laws in place for many years, including the Americans with Disabilities Act of 1990, Fair Housing Act of 1968, Stafford Act of 1988, and Rehabilitation Act of 1973, the interpretation and application of those laws in a postdisaster setting was inconsistent. In some cases, response organizations were under the impression the rules do not apply in disaster response and recovery settings. FNSS have also been managed in the past by sending the sheltered individuals from general population shelters to medical shelters and often separating them from their families in the process. However, most individuals with functional and access needs can be accommodated in general populations shelters. Following a series of lawsuits, FNSS became a priority, and new guidance was issued interpreting the laws and defining FNSS requirements.

FNSS must be incorporated into the planning process. A jurisdictional risk assessment provides a general idea of how many in the population have any degree of functional or access needs. The US Census Bureau estimates about 1 in 5 citizens have a disability and 1 in 10 have a severe disability. These disabilities fall into three broad categories including those who have difficulty:

- in the communicative domain (blind or have difficulty seeing; deaf or have difficulty hearing; having their speech understood)
- in the mental domain (learning disability, intellectual disability, developmental disability or Alzheimer's disease, senility, dementia, or any other mental or emotional condition interfering with everyday activities)
- in the physical domain (using a wheelchair, cane, crutches, or walker; difficulty walking or lifting; having a chronic medical condition including cancer, cerebral palsy, diabetes, epilepsy, high blood pressure, heart, lung, or gastrointestinal disorders; or any other condition limiting activity).
  Brault (2010).

Meeting these needs is accomplished through reasonable modifications to policies, practices and procedures; provisions for DME, consumable medical supplies (CMS), and personal assistance services (PAS); accessible communication; and other reasonable goods and services. The Federal Emergency Management Agency released guidance in 2010, Guidance on Planning for Integration of Functional Needs Support Services in General Population Shelters, available at: http://www.fema.gov/pdf/about/odic/fnss_guidance.pdf. This document provides useful planning tips for both governmental and nongovernmental organizations working on general population shelter planning.

Capability 8: Medical Countermeasure Dispensing

An effective response to a public health emergency sometimes centers on the ability to rapidly deliver vaccines, antivirals, antibiotics, antitoxins, or other medical countermeasures (MCMs) to vulnerable or exposed populations. MCM-dispensing planning and

operations require multidisciplinary, multiagency partners, and subject matter experts. As with many other capabilities, the jurisdictional risk assessment is useful in defining the demographics and estimating potential MCM needs for various scenarios. Planning must include more than the MCMs. Consumable medical supplies and FNSS needs must be incorporated into the planning process. The medical countermeasure dispensing capability is summarized in Fig. 2-14.

MCM planning should include public and private sector input from public health, pharmacy, healthcare, law enforcement, EMS, military, volunteer organizations, and businesses including transport companies like the US Postal Service, FedEx, and UPS. The goal of the planning is to establish, equip and staff enough points of dispensing (PODs) with adequate throughput to reach every member of the community within 48 hours or as quickly as possible depending upon the scenario. This includes identifying facilities for open PODs, which are those open to the general public, as well as inviting local companies and organizations to dispense to their own employees and their families in a closed POD which is closed to all but their employees and families.

Planning must address an array of logistical and other details to ensure safe and effective MCM delivery. The resources and processes required for an effective POD include, but are not limited to, material transport and handling, cold storage, security, crowd control and communication, personal protective equipment, and administrative support and supplies. It is also important to keep in mind no drug is completely benign. Injecting or ingesting pharmaceutical substances will have unintended consequences for some, especially when an MCM dispensing activity is focused on a large population. Awareness materials must be shared with each individual when the MCM is delivered and include a procedure for reporting adverse reactions.

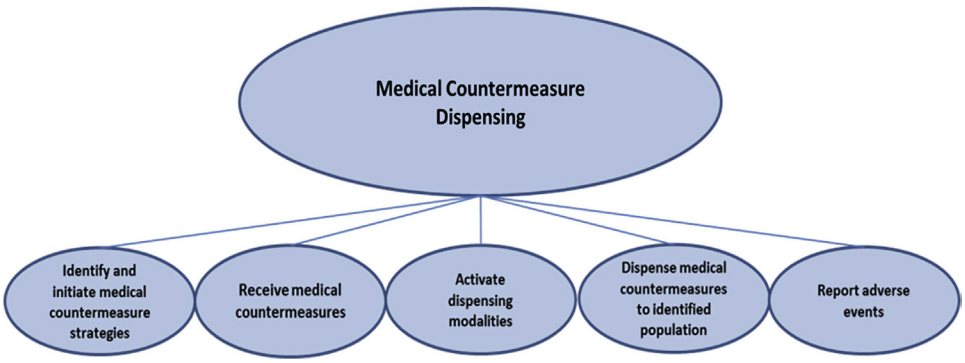

FIGURE 2-14 Medical countermeasure dispensing capability and functions.

Function 1: Identify and initiate medical countermeasure dispensing strategies.
Function 2: Receive medical countermeasures.
Function 3: Activate dispensing modalities.
Function 4: Dispense medical countermeasures to identified population.
Function 5: Report adverse events.
CDC (2011).

Medical Countermeasure Dispensing Example: Los Angeles County Department of Public Health, Community Partner Assessment Toolkit

Los Angeles County is one of the most populated and diverse communities in the United States with 88 cities and over 10 million residents speaking over 100 languages. This region represents one of the most challenging places in the world to accomplish rapid MCM distribution. The Los Angeles County Department of Public Health (LACDPH) partnered with the Naval Postgraduate School and the Centers for Disease Control and Prevention to develop a decision-support toolkit. The Community Partner Assessment Toolkit provides a method to explore alternative MCM delivery approaches.

The Microsoft Excel based tool is preprogrammed with multiattribute value function calculations providing the analytical platform. The tool guides the planner on where to find and how to enter data. The estimated number to be reached, staffing requirements, and security ratings may be entered for:

- Prepositioning medication for:
  - government employees and their families
  - hospital patients, staff and staff families
- Dispensing of medication to:
  - critical Infrastructure employees and their families
  - sheltered in populations
  - tourists, travelers, hotel employees and families
  - large private sector employers
  - students and faculty at colleges and universities
  - tribal Nations
- Up to three additional community partners

Planners can then adjust the number reached, staffing requirements, and security ratings to explore the trade-offs resulting from each alternative approach (LACDPH, 2012). This innovative tool provides planning perspective based on data and addresses one of the most important challenges of MCM dispensing by communicating complex options in an understandable format to decision-makers during a public health emergency.

Capability 9: Medical Material Management and Distribution

Public health coordinates medical material management and distribution when a public health emergency overwhelms the routine community supply chain. Planning for this capability includes identification of receiving and storage sites, also referred to as Receipt, Staging and Storage (RSS) sites as a part of the federal Strategic National Stockpile (SNS) program. Transportation support must be established and staffing needs estimated based on the personnel numbers and skills required to operate the RSS site. Security processes and procedures must be established for both general operations and controlled substances. An inventory management system is essential to monitor the levels of medical materials throughout a crisis. The system must regularly provide inventory data to decision-makers.

Procedures and protocols must also be established and staff provided with training and exercises. The medical materiel management and distribution capability is summarized in Fig. 2-15.

As medical material is acquired from public or private sources, it must be stored in accordance with its manufacturer's recommendations. Processes for acquiring and resupplying medical material can include public and private sources. It may include local medical supply and pharmaceutical businesses, regional wholesalers, or requests to other states through the Emergency Management Assistance Compact process. If local and state assets are exhausted, a federal request can be submitted to the SNS program. Based on the incident, an allocation strategy and distribution process must also be established. In addition, a demobilization process must be developed to recover medical materials and supplies for final disposition.

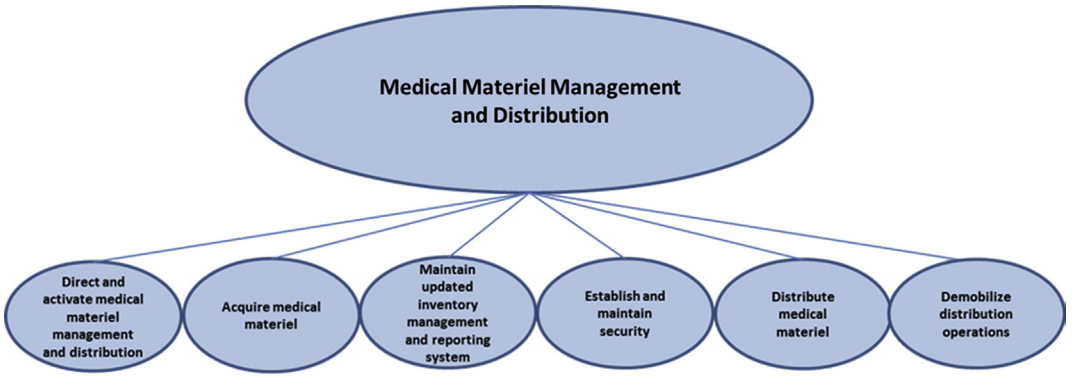

FIGURE 2-15 Medical materiel management and distribution capability and functions.

Function 1: Direct and activate medical materiel management and distribution.
Function 2: Acquire medical materiel.
Function 3: Maintain updated inventory management and reporting system.
Function 4: Establish and maintain security.
Function 5: Distribute medical materiel.
Function 6: Recover medical materiel and demobilize distribution operations.

Medical Materiel Management and Distribution Example: Idaho Inventory Management System (IIMS): Managing Supply Management and Strategic National Stockpile (SNS) Distribution

During the response to H1N1 the Idaho Department of Health and Welfare, Health Preparedness Program (IDHW/HPP) used manual processes for the receipt, staging and storage (RSS) operations. Realizing the department could improve their efficiency and accuracy, IDHW incorporated and exercised a new inventory management system called the Idaho Inventory Management System (IIMS), an electronic system using barcodes,

scanners, and laptop computers. The system was fully tested in a functional exercise by staff receiving just-in-time training (FEMA, 2012). The exercise demonstrated the system's ability to decrease both the time to respond and the number of errors.

Capability 10: Medical Surge

Public health serves a supporting role in medical surge during public health emergencies. This includes providing support for assessing immediate medical resource needs and providing health-related data to healthcare organizations and coalitions. This information may be used to decide when to activate medical surge plans. When an incident overwhelms the healthcare system, public health can deploy additional medical and nonmedical staff with resources to supplement existing facilities or establish alternate care sites. This includes deploying medical response assets from outside the immediate area, coordinating medical and nonmedical volunteers, and providing mental health/behavioral health support to victims and responders. Specialized assets can be requested, including pediatric equipment and supplies. If patients need to be transported out of the area, bed reporting can help identify the best patient movement strategy while patient and vehicle tracking systems can be used to maintain visibility on locations and estimated arrival times. Over the course of a medical surge, public health can provide media updates and public information including triage locations and access to other critical resources. Public health also coordinates the development of crisis standards of care to provide an ethical decision-making framework when resources are scarce. The medical surge capability is summarized in Fig. 2-16.

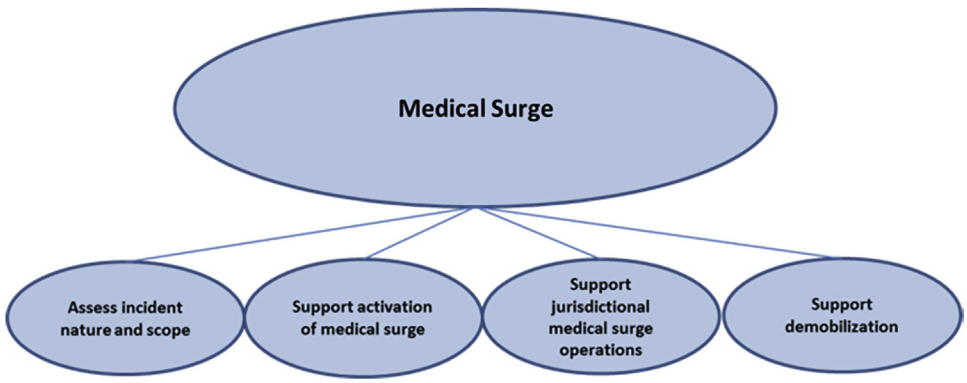

FIGURE 2-16 Medical surge capacity and functions.

Function 1: Assess the nature and scope of the incident.
Function 2: Support activation of medical surge.
Function 3: Support jurisdictional medical surge operations.
Function 4: Support demobilization of medical surge operations.

Medical Surge Example: Mesa County Health Department (Grand Junction, Colorado) Advanced Practice Center, Blueprint for the Use of Volunteers in Hospitals and Rural Medical Centers

Volunteer management is challenging during a disaster. This is especially true in rural areas where both medical and nonmedical surge capacity can be limited. There are often retired healthcare workers and others in surrounding communities who could supplement hospital staffing during a crisis but are often not utilized due to concerns about liability or meeting training requirements.

The Mesa County Advanced Practice Center (APC) partnered with a rural hospital and several volunteer organizations to develop a toolkit for preparing volunteers to be integrated into a medical surge operation. The toolkit includes information for both clinical and nonclinical volunteers. The APC coordinated between the healthcare facility and volunteer organizations to address liability concerns and policy requirements. Acceptable roles were identified for clinical and nonclinical volunteers and a toolkit was developed to facilitate replication of the process in other facilities (MCHD, 2010). The toolkit modified medical surge tools to facilitate better partnering with volunteers, simplified training and exercise materials, and created documentation for volunteer integration during a crisis.

Capability 11: Nonpharmaceutical Interventions

NPIs include an array of public health strategies to reduce the risk of disease transmission. These interventions include promoting protective measures and behaviors as well as enforcing more formal measures such as:

- individuals washing hands frequently, avoiding those who are ill, covering coughs and cleaning frequently touched surfaces
- communities implementing social distancing measures including school closures and cancellation of large congregate events; and promoting personal nonpharmaceutical measures
- businesses enforcing staying home when ill, promoting teleworking, cleaning frequently touched surfaces, and promoting personal nonpharmaceutical measures

These NPI strategies should be included in advanced planning for a variety of scenarios. Campaign materials can be designed in advance for NPI promotion during influenza and other recurring infectious disease threats. Legal, regulatory, and policy reviews must be accomplished to characterize the conditions under which actions such as isolation, quarantine, or restrictions of movement are allowable. The range of options and authorities should be vetted by legal experts and well documented in advance. Consideration must be given to unique scenarios such as radiological emergencies, which include reception centers and decontamination procedures. The nonpharmaceutical intervention capability is summarized in Fig. 2-17, and an example is given in Fig. 2-18.

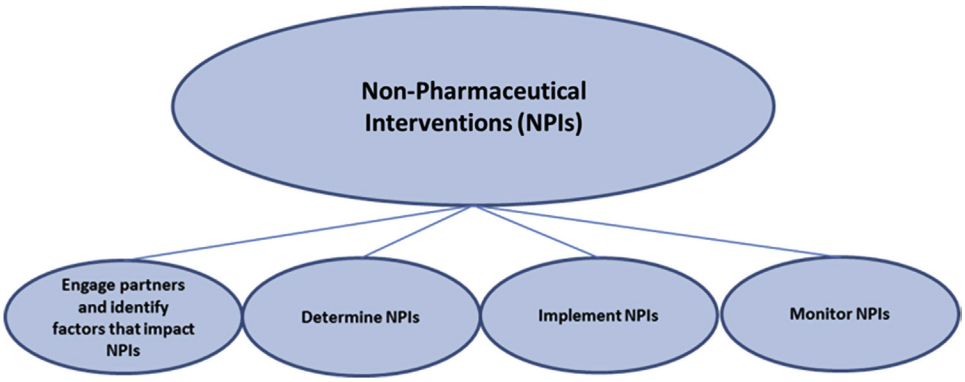

FIGURE 2-17 Nonpharmaceutical intervention capability and functions.

Function 1: Engage partners and identify factors that impact nonpharmaceutical interventions.
Function 2: Determine nonpharmaceutical interventions.
Function 3: Implement nonpharmaceutical interventions.
Function 4: Monitor nonpharmaceutical interventions.
CDC (2011).

Nonpharmaceutical Intervention Example: The 5th Guy Campaign (Florida)

Handwashing is the most important and effective NPI. Research indicates only one in five people wash their hands regularly. In 2007, the Florida Department of Health launched a humorous but effective campaign based on the message "Four out of five people wash their hands after using the restroom…Could someone talk to the fifth guy?" The 5th Guy Campaign created a character known as the fifth guy and was promoted on TV, radio, outdoor, print, and online (FDH, 2007). The campaign also included the use of social media and on-line videos. Unlike most health promotion efforts which focus on the positive benefits of a behavior, this campaign was designed to increase the negative stigma associated with lack of hand washing. (Plourde et al., 2008) More information can be found at: http://5thguy.com/.

FIGURE 2-18 5th Guy Campaign poster. *Courtesy of the Florida Department of Health.*

Capability 12: Public Health Laboratory Testing

The public health laboratory capability includes the capability to perform rapid and conventional detection, characterization, confirmatory testing, data reporting, investigative support, and laboratory networking to address actual or potential exposure to all-hazards (CDC, 2011). This capability is outlined in Fig. 2-19.

Public health laboratories play an essential role in responding to both natural and man-made disasters including chemical, biological, radiological, nuclear, and explosion threats. Like other preparedness capabilities, laboratories develop partnerships to support overall preparedness and response capacity. In the United States, the Laboratory Response Network (LRN) comprises over 150 laboratories including federal state, and local public health labs, the USDA, the FDA, amd environmental and veterinary labs. International partnerships include those with Canada, the United Kingdom, Australia, Mexico, and South Korea (CDC, 2014b).

The overall laboratory network is a tiered system with thousands of private and commercial "sentinel laboratories," including those located within hospitals. Sentinel laboratories can refer samples to more than 150 "reference labs" used for referrals and investigation. Reference labs can refer to the national laboratories, including the CDC and US Army Medical Research Institute for Infectious Diseases, to characterize strains of handle select or highly infectious agents (CDC, 2014c). This coordination requires effective exchange of information and samples. Samples must be managed in accordance with rigid guidelines for packaging and transporting while maintaining a forensic chain of custody.

Given the rarity of incidents requiring the handling of some threat agents, labs must accomplish proficiency in testing to maintain preparedness. There are specialized proficiency tests for labs designated to do biological testing (LRN-B), chemical testing (LRN-C), and also radiological (LRN-R) labs. In addition to testing proficiency, notification drills are held regularly to assure on-call epidemiologists and laboratorians can be reached at any time.

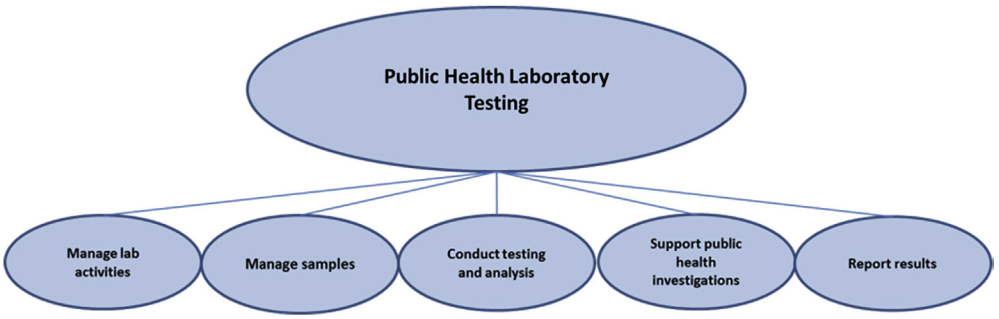

FIGURE 2-19 Public health laboratory testing capability and functions.

Function 1: Manage laboratory activities.
Function 2: Perform sample management.
Function 3: Conduct testing and analysis for routine and surge capacity.
Function 4: Support public health investigations.
Function 5: Report results.
CDC (2011).

Public Health Laboratory Testing Example: The Association of Public Health Laboratories' (APHL) Emerging Infectious Diseases Planning and Response Framework

The Association of Public Health Laboratories (APHL) established an Infectious Diseases Committee in 2004. Through their efforts, an Emerging Infectious Diseases Planning and Response Framework was developed in 2005 for laboratory professionals. It includes a comprehensive summary of important steps and activities to consider when preparing or responding to a major outbreak or emerging infectious disease threat. It includes sections on partnerships, communications, safety, regulatory, sample/specimen transport, testing, testing in the private sector, reporting and data management, staffing, surge, and miscellaneous actions (APHL, 2005). This simple yet comprehensive eight-page checklist laid the groundwork for laboratory preparedness advancement in many labs across the United States and can be found among many more exceptional resources on the APHL Website: http://www.aphl.org/aphlprograms/preparedness-and-response/Pages/Training-and-Tools.aspx.

Capability13: Public Health Surveillance and Epidemiological Investigation

Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems (Last, 2001). Epidemiological information can be used to anticipate and trigger public health emergency response activities for a variety of threats. In addition, epidemiological analysis of disaster morbidity and mortality can lead to mitigation and preparedness measures which reduce the public health impact of future disasters. The public health surveillance and epidemiological investigation capability is summarized in Fig. 2-20.

FIGURE 2-20 Public health surveillance and epidemiological investigation capability and functions.

Function 1: Conduct public health surveillance and detection.
Function 2: Conduct public health and epidemiological investigations.
Function 3: Recommend, monitor, and analyze mitigation actions.
Function 4: Improve public health surveillance and epidemiological investigation systems.
CDC (2011).

Prior to an incident, emergency response epidemiological processes and protocols should be in place to address health information management. Confidentiality and other legal issues must be addressed before a disaster. This includes an understanding of how routine processes and data sharing may change when there is a public health emergency. Data sources may include routine reportable condition surveillance and syndromic surveillance. Additional data sources may be added during a response to include specific morbidity and mortality variables from response activities. When an incident occurs, surveillance and epidemiological investigations can also guide decisions on appropriate response activities and targeting of resources. Enhanced cooperation between epidemiologists and public health preparedness professionals provides more effective matching of resources to the needs of the impacted population.

Public Health Surveillance and Epidemiological Investigation Example: Traveler Screening and Monitoring to Reduce US Ebola Risk

The 2014–2015 US Ebola outbreak response led to new processes for screening and monitoring travelers arriving in the United States from nations with risk for Ebola exposure. Arrivals from these nations were restricted to five major airports where Department of Homeland Security staff asked screening questions, checked temperatures, and assessed the traveler for any signs or symptoms of disease. After the screening process, those travelers allowed to proceed were given information on Ebola, a thermometer with a temperature log and instructions for taking and recording their temperature and any associated symptoms, as well as instructions on whom to contact if they develop symptoms. They continued their travel and were placed in contact with the state or local health department at their final destination. Once reaching their final destination, travelers were assessed by the state or local public health officials and given additional instructions which varied from one jurisdiction to another. For 21 days following their departure from Africa, they were placed on one of two monitoring options:

- Active monitoring: For low risk travelers, a public health worker checks at least once per day to see if the travel has a fever or symptoms. These checks have been accomplished online, over the phone, or with a face to face visit. If the traveler develops a temperature or symptoms, he/she is referred for medical care and testing.
- Direct active monitoring: For travelers with higher risk, a public health worker will directly observe for temperature measurement and symptoms. This is done either in person or over video chat using applications such as Skype or FaceTime.
  CDC (2015).

This screening and monitoring process provided valuable insights into methods, communication, reporting, legal issues, and provision of basic needs for those with restricted movement. The process reduced the possibility of an undiagnosed or incubating Ebola case exposing others. It also established an approach which may be modified and used in the future for other high consequence emerging infectious disease threats.

Capability 14: Responder Safety and Health

The responder safety and health capability focuses primarily on public health and healthcare staff protection, but many protective measures are applicable beyond health responders. An assessment of possible physical and mental/behavioral health must be accomplished prior to responding to an incident and in conjunction with other responding agencies. There should also be general safety training provided in advance and a specific safety briefing developed according to the specific hazards posed by the deployment. For any incident, a safety officer should be appointed to work with subject matter experts in order to characterize the risks and hazards specific to the incident. Safety officers are both included in emergency operations centers and deployed in teams to assure safe front line operations. Safety and health recommendations should be developed and shared with incident command staff and deploying individuals. Recommendations should include personal protective actions and equipment. Some scenarios may also necessitate medical countermeasures. Predeployment screening of responders should be in place to identify any acute or chronic conditions which may predispose the deploying individual to additional risk. The responder safety and health capability is summarized in Fig. 2-21.

During deployments, continual reassessments should be carried out to identify changing or emerging risks. Partner response organizations may provide additional situational awareness as conditions change. Information received may inform decision-making, including modifying protective equipment or actions. As conditions warrant, suspension or termination of activities may be considered. Postdeployment activities include debriefing and determination of the need for additional physical or mental/behavioral screening or follow-up.

FIGURE 2-21 Responder safety and health capability and functions.

Function 1: Identify responder safety and health risks.
Function 2: Identify safety and personal protective needs.
Function 3: Coordinate with partners to facilitate risk-specific safety and health training.
Function 4: Monitor responder safety and health actions.

Responder Safety and Health Example: OSHA, Best Practices for Protecting EMS Responders during Treatment and Transport of Victims of Hazardous Substance Releases

The Occupational Safety and Health Administration (OSHA) published guidance and best practices in 2009 called, "Best Practices for Protecting EMS Responders during Treatment and Transport of Victims of Hazardous Substance Releases." This comprehensive, 104 page guide discusses critical questions concerning the role of EMS in responding to patients possibly exposed to hazardous substances. The guide outlines key points EMS employers should discuss with employees and decisions which should be made before responding to a call with hazardous substances. Sources of information and processes to accomplish hazard assessments are presented. Detailed information is included on associated training guidelines, personal protective equipment requirements and a summary of OSHA requirements. The guide also includes best practices, references, tools and tips. It is an indispensable resource for EMS agencies and a model practice in sharing specific responder safety and health information in a comprehensive, yet user friendly, format. The document is available on line at: https://www.osha.gov/Publications/OSHA3370-protecting-EMS-respondersSM.pdf.

Capability 15: Volunteer Management

Volunteers are a tremendous resource during public health emergencies and disasters. Successful response to and recovery from large-scale disasters often relies heavily upon an array of volunteers. Volunteers include both nontechnical (eg, storm debris removal) and highly specialized (eg, healthcare professionals). In the United States, many clinical and nonclinical volunteers are managed through the Medical Reserve Corps (MRC) Program. The MRC is

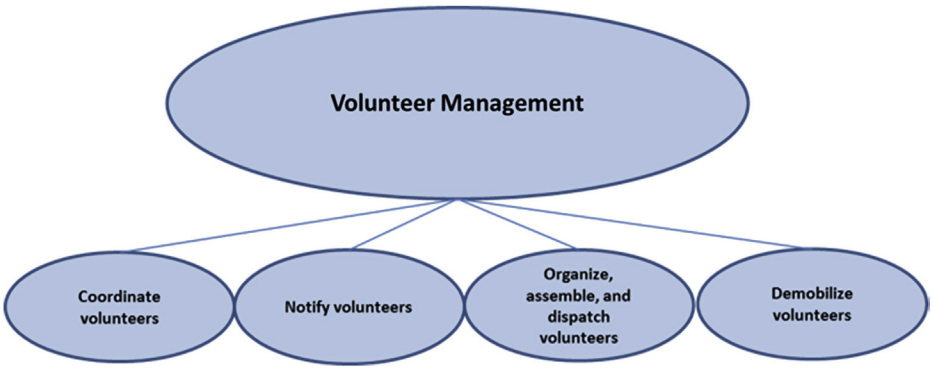

FIGURE 2-22 Volunteer management capability and functions.

Function 1: Coordinate volunteers.
Function 2: Notify volunteers.
Function 3: Organize, assemble, and dispatch volunteers.
Function 4: Demobilize volunteers.
CDC (2011).

a nationwide network of nearly 1000 local units with a total of over 200,000 local volunteers. MRC volunteers include public health, mental health, and healthcare professionals, as well as some volunteers with no health or medical backgrounds. MRC members provide additional capacity which strengthens response capabilities and enhances community disaster resilience. The volunteer management capability is summarized in Fig. 2-22.

Other sources of volunteer support include nongovernmental agencies (NGOs) which provide the largest volunteer force in most disasters. NGO activities are diverse and include cleanup and rebuilding, donations management, case management, disaster victim advocacy, mass care, feeding, disaster behavioral health support and more. NGOs providing disaster relief operations on a regular basis and those integrated into response planning are called VOADs. They include the American Red Cross, Salvation Army, and other charitable organizations providing consistent services and support.

Volunteer Management Capability Examples: Medical Reserve Corps (MRC) Responses

- The Dallas County MRC supported response operations in Dallas, Texas during the October, 2014 response to the first US diagnosed Ebola case. Community concerns were deep and 95 MRC volunteers served 641 hours supporting the call center, sharing accurate information to dispel concerns, and canvassing neighborhoods.
- In Vermont, the Northwest Vermont & Chittenden County MRC responded to a March 2015 tuberculosis (TB) concern. A person who worked at an elementary school was diagnosed with active TB, and the volunteers provided TB testing at the school and a local daycare.
- The Rhode Island MRC supported response operations in February 2015, to two cases of meningococcal B at a college. The State of Rhode Island Department of Health coordinated the vaccination of over 3000 students using MRC volunteers who donated over 600 hours of service (MRC, 2015).

Summary

Public health preparedness programs cut across all routine public health services and involve an array of public health stakeholders and partners that the public health infrastructure comprises. These programs, processes and partners operate within an emergency management structure to reduce morbidity and mortality resulting from a public health emergency or disaster. The current US public health preparedness programs were established shortly after the terrorist attacks of 2001 and have evolved for over a decade as lessons have been learned from major public health emergencies such as the 2009–2010 H1N1 pandemic, numerous large-scale foodborne outbreaks, the 2014–2015 Ebola outbreaks and looming threats of MERS and avian influenza. Major disasters like Hurricane Katrina and Superstorm Sandy have highlighted the importance of maintaining the “all-hazards” approach to public health preparedness and response.

The 2011 introduction of public health preparedness capabilities established a framework allowing for a much clearer understanding of the breadth and depth of the developing discipline of public health preparedness. The 15 capabilities with their associated functions provide a structure for jurisdictional planning. Jurisdictions can use the capabilities to identify and prioritize gaps and provide a basis from which to develop goals, objectives and desires outcomes.

Websites

Centers for Disease Control and Prevention (CDC), Emergency Preparedness and Response. http://emergency.cdc.gov/.

Centers for Disease Control and Prevention (CDC), 2011. Public Health Preparedness Capabilities: National Standards for State and Local Planning. http://www.cdc.gov/phpr/capabilities/.

Centers for Disease Control and Prevention (CDC), Funding and Guidance for State and Local Health Departments. http://www.cdc.gov/phpr/coopagreement.htm.

Center for Infectious Disease Research and Policy, University of Minnesota, Public Health Practices. http://www.cidrap.umn.edu/public-health-practices.

Federal Emergency Management Agency (FEMA), National Response Framework. https://www.fema.gov/national-response-framework.

Office of the Assistant Secretary for Preparedness & Response. http://www.phe.gov/preparedness/Pages/default.aspx.

Office of the Assistant Secretary for Preparedness and Response, January 2012. Healthcare Preparedness Capabilities: National Guidance for Healthcare System Preparedness. http://www.phe.gov/coi/Pages/capabilities.aspx.

World Health Organization, Emergency and Disaster Risk Management for Health. http://www.who.int/hac/techguidance/preparedness/en/.

World Health Organization, Natural Disaster Profiles. http://www.who.int/hac/techguidance/ems/natprofiles/en/.

World Health Organization, Technical Guidelines in Emergencies. http://www.who.int/hac/techguidance/en/.

References

Association of Public Health Laboratories (APHL), 2005. Emerging Infectious Diseases Planning and Response Framework. Available at: http://www.aphl.org/aphlprograms/infectious/emerging/Documents/EID_2005April_Emerging-Infectious-Diseases-Planning-and-Response-Framework.pdf.

Brault, M.W., 2010. Americans with Disabilities: 2010 Household Economic Studies.

Boy Scouts of America (BSA), 1998. Boy Scout Handbook, 11th ed. Boy Scouts of America, Pineville, NC, p. 54.

Centers for Disease Control and Prevention (CDC), March 2011. Division of State and Local Readiness (DSLR), Public Health Preparedness Capabilities. National Standards for State and Local Planning. Available at: http://www.cdc.gov/phpr/capabilities/.

Centers for Disease Control and Prevention (CDC), 2014a. The Public Health System and the 10 Essential Public Health Services. Available at: http://www.cdc.gov/nphpsp/essentialservices.html.

Centers for Disease Control and Prevention (CDC), 2014b. Facts about the Laboratory Response Network. Emergency Preparedness and Response. Available at: http://emergency.cdc.gov/lrn/factsheet.asp.

Centers for Disease Control and Prevention (CDC), 2014c. Laboratory Network for Biological Terrorism. Available at: http://emergency.cdc.gov/lrn/biological.asp.

Centers for Disease Control and Prevention (CDC), 2015. Fact Sheet: Screening and Monitoring Travelers to Prevent the Spread of Ebola. Available at: http://www.cdc.gov/vhf/ebola/travelers/ebola-screening-factsheet.html.

Center for Infectious Disease Research and Policy (CIDRAP), 2015a. Disaster Planning in San Francisco's Chinatown Trains, Empowers Community Members as Responders during First 72 Hours. Available at: http://www.cidrap.umn.edu/practice/disaster-planning-san-francisco%E2%80%99s-chinatown-trains-empowers-community-members-responders.

Center for Infectious Disease Research and Policy (CIDRAP), 2015b. Cross-border Collaborations Enhance Preparedness at an International Event. Available at: http://www.cidrap.umn.edu/practice/cross-border-collaborations-enhance-preparedness-international-event-wa.

Center for Infectious Disease Research and Policy (CIDRAP), 2015c. Dark Site Stores Emergency Communications until Crisis Occurs. Available at: http://www.cidrap.umn.edu/practice/dark-site-stores-emergency-communications-until-crisis-occurs-ca.

Claudel, P., 1965. The american elasticity. In: Works in Prose. La Pleiade. Gallimard, Paris, France, pp. 1204–1208 (in French).

Covello, V.T., Allen, F.H., April 1988. Seven Cardinal Rules of Risk Communication. Environmental Protection Agency (EPA) Pamphlet, Washington, DC. OPA-87–020.

Florida Department of Health (FDH), 2007. The 5th Guy Campaign.

Federal Emergency Management Agency (FEMA), 2012. Idaho Inventory Management System (IIMS): Managing Supply Management and Strategic National Stockpile (SNS) Distribution. FEMA Innovative Practice Report. Available at: file:///C:/Users/Owner/Downloads/nps68-012314-02.pdf.

Federal Emergency Management Agency (FEMA). (2015) Ready.gov, Prepare, Plan, Stay Informed. Available at: http://www.ready.gov/.

Hicks, C.B., December 1963. The incredible gateway arch: America's mightiest national monument. Pop. Mech. Hear. Mag. 120 (6), 89. ISSN: 0032-4558.

Health Level Seven International (HL7), 2015. About HL7. Available at: http://www.hl7.org/about/index.cfm?ref=nav.

Ho, M.C., Shaw, D., Lin, S., Chiu, Y.C., 2008. How do disaster characteristics influence risk perception? Risk Anal. 28 (3), 635–643.

Holling, C.S., 1973. Resilience and stability of ecological systems. Annu. Rev. Ecol. Syst. 4, 1–23.

Hollnagel, E., Woods, D., Leveson, N. (Eds.), 2006. Resilience Engineering: Concepts and Precepts. Ashgate, Aldershot, UK.

Institute of Medicine (IOM), 1988. The Future of Public Health. National Academy Press, Washington, DC. Committee for the Study of the Future of Public Health.

King County Medical Examiner's Office (KCMEO) and the Preparedness Section of Public Health – Seattle & King County, 2015. Mass Fatality and Family Assistance Operations Response Plan. Version 4. Available at: http://www.kingcounty.gov/healthservices/health/preparedness/plans/Family-Assistance.aspx.

Keen, J., Stone, A., June 13, 2008. Boy Scouts Recount Survival Stories of Deadly Iowa Tornado. USA Today. Retrieved August 7, 2008 www.usatoday.com/weather/storms/tornadoes/2008-06-12-boyscouts_N.htm.

Los Angeles County Department of Public Health (LACDPH), 2012. Community Partner Assessment Toolkit (cPAT). NACCHO 2012 Model Practice available at: https://eweb.naccho.org/eweb/dynamicpage.aspx?webcode=mpview&customerkey=7585F6C6-C8B2-4C33-8A80-990F734E63A7&am1_key=64F30C28-405A-4491-8255-ADB0F030EE11&am2_key=F9356119-497E-4F73-B7A7-45ADA93CA21B&pt=5.

Last, J.M. (Ed.), 2001. Dictionary of Epidemiology, fourth ed. Oxford University Press, New York, p. 61.

McClung, M., 2012. HANDI – A Handy App for Public Health. Centers for Disease Control and Prevention, Public Health Matters Blog. Posted on February 1, 2012. Available at: http://blogs.cdc.gov/publichealthmatters/2012/02/handi-a-handy-app-for-public-health/.

Mesa County Health Department, Advanced Practice Center (MCHD), 2010. Blueprint for the Use of Volunteers in Hospitals and Rural Medical Centers. Available at: http://health.mesacounty.us/apc/.

Medical Reserve Corps (MRC), 2015. Did You Know? Available at: https://www.medicalreservecorps.gov/DidYouKnow.

NICOS Chinatown Disaster Preparedness Committee (NICOS), 2007. San Francisco Chinatown Disaster Response Plan. Available at: http://www.nicoschc.org/DPbooklet%2012.15.08.pdf.

Office of the Assistant Secretary for Preparedness and Response (OASPR), January 2012. Healthcare Preparedness Capabilities: National Guidance for Healthcare System Preparedness. Hospital Preparedness Program (HPP); Centers for Disease Control and Prevention (CDC), Division of State and Local Readiness (DSLR). Available at: http://www.phe.gov/coi/Pages/capabilities.aspx.

Plourde, C., Cook, L., Mitchell, P., Jennings, C., 2008. Talk to the Fifth Guy: A Lesson in Social Marketing. Cases in Public Health Communication & Marketing. 2:39–54.

Riad, J.K., Norris, F.H., Ruback, R.B., 1999. Predicting evacuation in two major disasters: risk perception, social influence, and access to resources. J. Appl. Soc. Psych. 29 (5), 918–934.

Taylor, K., Kolberg, A., Lien, O., Lis, R., 2012. Fatality Management from a Public Health Perspective. Available at: http://www.kingcounty.gov/healthservices/health/preparedness/plans/Family-Assistance.aspx.

U.S. Department of Health and Human Services (HHS), September 2007. Medical Surge Capacity Handbook, a Management System for Integrating Medical and Health Resources during Large-scale Emergencies, second ed. Office of the Assistant Secretary for Preparedness and Response (OASPR). Available at: http://www.phe.gov/preparedness/planning/mscc/handbook/pages/appendixc.aspx.

Waugh, W.L., 2000. Living with Hazards, Dealing with Disasters: An Introduction to Emergency Management. M.E. Sharpe, Armonk, NY.

Yates, R.C., 1952. "Catenary." A Handbook on Curves and Their Properties. J. W. Edwards, Ann Arbor, MI, pp. 12–14.

3

Community Disaster Resilience

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OBJECTIVES

- Differentiate community resilience from community disaster resilience.
- List the core characteristics of a disaster-resilient community.
- Describe the "all hazards, all agencies, all people" approach.
- Explain the benefits of assessing community disaster resilience.
- Explain the benefits of participatory action research.
- Define community self-reliance.
- Explain the role of nongovernment organizations (NGOs) in community disaster resilience.
- Explain collaborative community resilience building.
- Describe community engagement strategies.
- Define posttraumatic growth.

When considering the diverse impacts of natural disaster events, it is important to note that these events are only considered "disasters" if they disrupt the normal functioning of a community due to losses that exceed the ability of the affected community to cope. In other words, if communities are better able to mitigate, prepare for, respond to, and recover from disruptions, there will conceivably be drastically fewer disasters. This capacity for self-reliance and self-mobilization is a central feature of resilient communities, and so with this in mind, the following chapter will explore the role community resilience plays across all phases of emergency management and in disaster risk reduction. The chapter addresses two critical questions:

1. How do communities become empowered to take responsibility for their own disaster mitigation and preparedness efforts?
2. What are the best ways to support communities in responding to and recovering from disasters?

Understanding Community Resilience

The concept of resilience has evolved in less than a decade from a term used within the disciplines of material sciences and environmental studies to become a concept used liberally and enthusiastically by policy makers, practitioners, and academics across a plethora of disciplines (Cork, 2010; McAslan, 2010). The term "resilience" takes on different meanings within disciplinary boundaries and is often not clearly defined or explained (Cork, 2010).

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Simply put, in its broadest application resilience describes how well a system is able to adapt positively when faced with adversity and cope with abnormal or unexpected threats without changing beyond recognition. The concept of resilience can be used to discuss any system (ecological, social, economic, mechanical, etc.), and within each system it can be considered at different scales from the micro to the macro, the individual to the societal (Gibson and Tarrant, 2010). However, resilience is not always a desirable trait. Core to the concept of resilience is a strong focus on avoiding any significant changes to the essential character of a system and perpetuating key structures and functions of that system. In other words, resilience acts to conserve the status quo (Cork, 2010), and this function can become undesirable if the status quo fails to address issues that will inhibit the long-term viability and sustainability of a system. For this reason, resilience cannot be considered in isolation from adaptability and transformability (Cork, 2010).

The term *community resilience* is used to describe the interconnected network of systems that directly impact human society at a grassroots community level, including the socioeconomic, ecological, and built environments. A community is resilient when:

> *...members of the population are connected to one another and work together, so that they are able to function and sustain critical systems, even under stress; adapt to changes in the physical, social or economic environment; be self-reliant if external resources are limited or cut off; and learn from experience to improve itself over time.*
>
> *Arbon et al. (2012).*

While the resilience of individuals, families, or specific organizations are key components of community resilience, as a whole a resilient community is greater than the sum of its parts (Parker, 2010). Meaning that a resilient system is a complete, complex, and interconnected system which contains "many more links than we can comprehend with simple cause and effect models" (Cork, 2010).

Understanding, measuring, and assessing community resilience requires a keen awareness of the links and relationships between the different scales of governance and different systems which are directly and indirectly affecting communities. Developing strategies for building and enhancing community resilience requires an understanding that vulnerability at any level translates to an increased vulnerability in other areas of the larger system. As an example, in a community where the transportation system is vulnerable to extreme weather events such as flooding or extreme snowstorms, this causes vulnerabilities elsewhere, as disruptions to transportation impact people's abilities to get back to work as well as the community's access to a constant supply of food and fuel. Although several theoretical models articulating the factors that contribute to community resilience do exist (Norris et al., 2008; Pfefferbaum et al., 2007, 2008), as a result of the sophisticated level of systems thinking necessary to understand community resilience, there is currently limited evidence for what practical strategies are most effective for building and enhancing community resilience (Chandra et al., 2010).

As stated in chapter Public Health Preparedness History and Policy of this textbook, the key vision put forth in the US National Preparedness Goal for enhanced disaster preparedness and disaster risk reduction is "A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk" (DHS, 2011). In order to achieve the level of resilience described in this vision, there is a need for governments and emergency management agencies to integrate community resilience building into their core business and find ways to meaningfully include everyone in the processes of emergency management.

Understanding Community Disaster Resilience

Within the emergency management sector, the concept of resilience is widely accepted as a critical part of any comprehensive emergency management strategy. The incorporation of resilience into processes of disaster risk reduction is articulated most significantly in the Hyogo Framework for Action 2005–2015. This framework was endorsed by 168 UN member states at the World Conference on Disaster Reduction in Kobe, Japan in 2005, and urged all countries to make major efforts to reduce their disaster risk by 2015 (International Strategy for Disaster Reduction, 2005). Despite the enthusiastic acceptance of the concept of disaster resilience, many stakeholders involved in practical resilience building do not have an agreed-upon definition for the concept, nor do they have a clear universal set of indicators by which to measure and assess community resilience (Chandra et al., 2010). While some critics warn that the concept of resilience is too ambiguous and at times contradictory to be relied on as a central pillar for disaster risk reduction, the differences between the many definitions of resilience are not as wide as some literature may suggest (McAslan, 2010).

In the context of emergency management, the term "community resilience" is used to describe the broad set of indicators that help explain why some communities are better able to cope and "bounce back" from disaster events, in comparison with others. A 2011 US Presidential Decision Directive described community resilience as "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies" (Obama, 2011). The United Nations Office for Disaster Risk Reduction defines resilience as:

> *The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.*
>
> *UNISDR (2007).*

While the capacity to cope with disasters is a key indicator of community resilience, it is only one of a broad set of considerations that contribute to a holistic understanding

of community resilience. For this reason, these definitions would be more accurately described as definitions for *community disaster resilience*.

The concept of community disaster resilience speaks more precisely of a community's capacity to adapt to change, handle disruption, and respond in a positive and timely manner to emergencies, while continuing to sustain critical systems and maintain the community's unique character (Cutter et al., 2008). In other words, a disaster-resilient community is better able to overcome adversity with less permanent impairment to its social, economic, health, and security functions. Importantly, an understanding of community disaster resilience must be inclusive of the extent to which natural ecosystems are able to continue to support a community's economic and social welfare while successfully absorbing the influence of human activity (Cork et al., 2008).

The term "adaptive capacities" is used to describe the dynamic attributes of the natural, built and human resources upon which community disaster resilience relies. These capacities include: robustness, redundancy and rapidity. These "transformational characteristics are what distinguish 'community resilience' from other ways of characterising community strengths, such as 'community competence' or 'social capital'" (Norris et al., 2007).

Critical to any understanding of the concept of community disaster resilience is a carefully considered understanding of the word "community." The word community can be used to describe everything from small grassroots groups of interests, to groups identifiable by their socioeconomic, cultural, political or ethnic makeup, to online groups, and groups bound by geography such as neighborhoods, states and nations. All communities are composed of "built, natural, social, and economic environments that influence one another in complex ways" (Norris et al., 2007). Disaster-resilient communities share many common characteristics, including: a basic level of preparedness which enables them to face threats and events which are abnormal in terms of their scale, form or timing; ability and willingness to adapt to a changing and sometimes threatening environment; tenacity and commitment to survive; and, a willingness of communities and organizations to rally around a common cause and a shared set of values (McAslan, 2010).

Core Characteristics of a Disaster-Resilient Community

The Australian National Emergency Management Committee was tasked to drive the development of a "National Strategy for Disaster Resilience" which was subsequently released in 2009 (COAG, 2009). This strategy document provides a useful list of 10 core characteristics that make for a disaster-resilient community; these are:

1. People have comprehensive local information about risks and hazards, including who is more vulnerable and what actions they can take in each phase of emergency management. They also understand the risks and hazards that may affect them locally, in their homes, workplaces, and their geographic region, as well as broader risks facing the country/globe.
2. People have taken steps to anticipate disasters and to protect themselves, their assets and their livelihoods, including their homes and possessions, cultural heritage and economic

capital, therefore minimizing physical, economic and social losses. They have committed the necessary resources and are capable of organizing themselves before, during and after disasters which helps to restore social, institutional and economic activity.

3. People work together with local leaders using their knowledge and resources to prepare for and deal with disasters. They use personal and community strengths and existing community networks and structures; a resilient community is enabled by strong social networks that offer support to individuals and families in times of crisis.
4. People work in partnership with emergency services, their local authorities, and other relevant organizations before, during, and after emergencies. These relationships ensure that community resilience activities are informed by local knowledge, can be undertaken safely, and complement the work of emergency service agencies.
5. Emergency management plans are resilience-based, to build disaster resilience within communities over time.
6. Communities, governments, and other organizations take resilience outcomes into account when considering and developing core services, products, and policies. They are adaptive and flexible to respond appropriately in disasters.
7. The emergency management volunteer sector is strong.
8. Businesses and other service providers undertake wide-reaching business continuity planning that links with their security and emergency management arrangements.
9. Land use planning systems and building control arrangements reduce, as far as is practicable, community exposure to unreasonable risks from known hazards, and suitable arrangements are implemented to protect life and property.
10. Following a disaster, a satisfactory range of functioning is restored quickly. People understand the mechanisms and processes through which recovery assistance may be made available, and they appreciate that support is designed to be offered, in the first instance, to the most vulnerable community members.
COAG (2009).

Central to each of these characteristics is the need for a collaborative, cross-sectoral approach which takes into consideration not only the physical hazards and assets of a community, but also factors such as social capital, community competence, economic development and information, and communication strategies (Norris et al., 2007).

The "All Hazards, All Agencies" Approach

One of the greatest inhibitors to community disaster resilience building to date has been the challenge of integrating resilience building into the core business of governments and emergency management agencies. Current thinking around emergency management is still largely focused on the role of agencies across the four phases of emergency management: mitigation, preparedness, response, and recovery, as shown in Fig. 3-1.

These four phases of emergency management can be understood to operate as part of the two-pronged approach to emergency management—the "all hazards" and "all

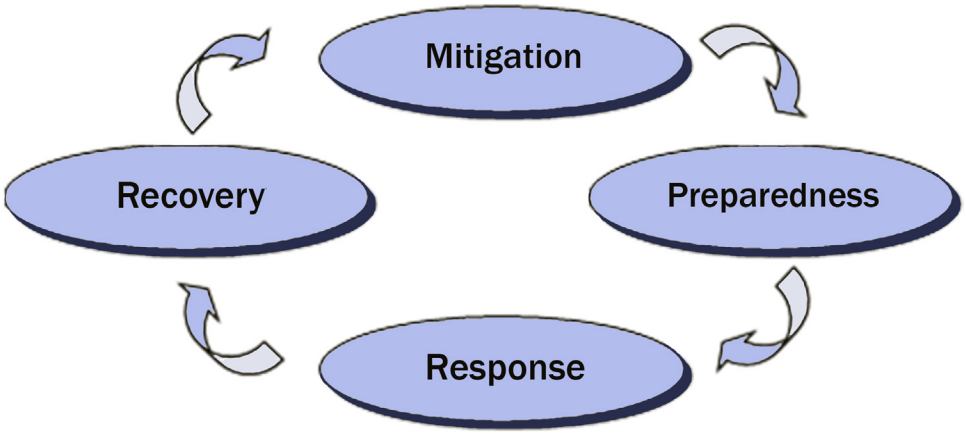

FIGURE 3-1 Four phases of emergency management.

agencies" approach (see Fig. 3-2)—where all agencies are involved in a comprehensive processes of mitigation, preparation, response, and recovery to all hazards.

- **"All hazards" approach**: The "all hazards" approach to emergency management necessitates that a broad preparedness approach is in place not only for hazards that have already occurred or occur on a regular basis, but for all possible hazards, including less common natural events such as tsunamis and volcanic eruptions, or man-made threats such as terrorist attacks.
- **"All agencies" approach**: An "all agencies" approach to emergency management calls for all government and nongovernment emergency management agencies to be involved throughout the four phases of emergency management. Ideally the "all agencies" approach should be inclusive of agencies and organizations from outside the emergency management sector, including private sector and volunteer organizations.

In countries where emergency management thinking has developed even greater sophistication, an "all agencies" approach incorporates high levels of cooperation, collaboration, and resource sharing among all the different agencies throughout the four phases of mitigation, preparation, response, and recovery.

This model for emergency management, which is "deeply rooted in a military-style top-down national approach" (Hebert, 2014), is efficient and very comprehensive, as it relies on highly specialized, well-trained agencies funded and supported by governments. However, this model faces two significant challenges: Firstly, this model is both incredibly labor and resource intensive, making it extremely costly for governments. Secondly, it is becoming clear that not only does this model fail to build community disaster resilience, in many cases it has actually weakened community resilience. This is because this model almost always completely excludes community stakeholders from its processes and from decision-making around disaster risk reduction. At the same time this model gives people

a false sense of security, elevating their expectations of governments and leading to unrealistic expectations that immediate assistance will be available to them in the case of an emergency (Hebert, 2014). In reality, particularly in the case of large-scale natural disasters:

> *...governments may not be able to deliver and meet such high expectations in a time of disaster. Furthermore, external responses at times undermine local initiatives, replace local capacities, and even spoil the effect of community-based organisations.*
>
> *Hebert (2014).*

In many communities this model of emergency management has led to a culture of "learned helplessness" (Douglas, 2010), where communities become totally reliant on government and emergency management agencies to guide, direct, and support them during all phases of emergencies.

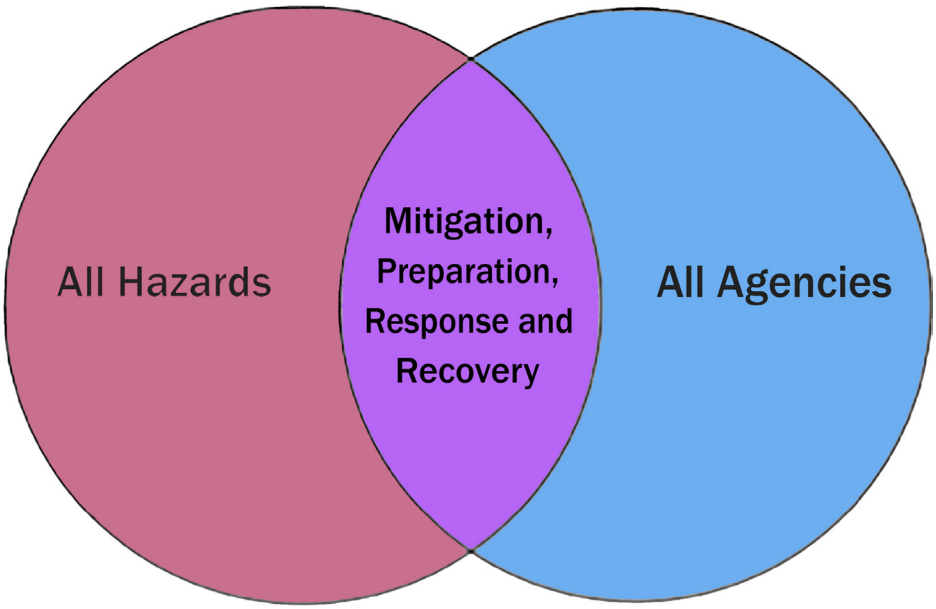

FIGURE 3-2 All hazards, all agencies approach.

An example that demonstrates how this learned helplessness manifests in ways that decrease community resilience and self-reliance can be observed when considering the majority of organizational evacuation plans. Most evacuation plans, whether for a business, school, organization, or even in the home, stop abruptly at the point when people get to a designated "meeting area." This evacuation meeting area is often just outside the building in question, and the unstated assumption at this point is that once a building is evacuated, people will then be provided with further instruction as to what they should do from an appropriate authority. However, in the case of a significant disaster, this expectation both

is unrealistic considering the limited human and material resources available, and leaves people at great risk. This is particularly true for those who are already considered vulnerable groups such as children, people with mental or physical disabilities, people living in aged care facilities, or people who are institutionalized (eg, prisoners). However, this does not necessarily need to be the case, as demonstrated in the case study below.

Case Study: Redland Aged Care Providers Group, Queensland, Australia

Aged care facilities, nursing homes and retirement villages are seen to be particularly vulnerable to the impacts of disasters. In 2010 in Redland, a medium-sized urban community just south of Queensland's capital city of Brisbane, Australia, a group of CEOs from a range of aged care and retirement villages were brought together to discuss emergency management and business continuity planning. The providers were asked to discuss their evacuation plans and identify how many ambulances they would need to support those in need of medical or mobility assistance. It soon became apparent that if a large-scale evacuation were to occur in the region, there would not be enough ambulances to respond to their needs. The represented agencies decided to put in place a formal arrangement for sharing their existing assets, resources, and staff in the event of a full extended evacuation. The group, made up of business competitors, drafted a formal memorandum of understanding stating their aims to:

- provide practical support/resource sharing in the event of emergency where the impact requires the evacuation of residents to an off-site location,
- mitigate risks within the residential aged care facilities/retirement villages in an emergency or evacuation event, and
- provide valuable support to staff and residents to ensure continuity of care and effective care (Redlands City Council, 2010).

In their plan, they enlisted additional support of community groups outside the aged care sector including the Rotary and the Queensland Ambulance Service. Fortunately, none of the agencies in the Redland Aged Care Providers Group were directly affected by the 2011 Queensland floods. However, thanks to their extended planning measures, they were able to offer support during this disaster event to other aged care providers in the greater Brisbane area. This model of self-reliance and collaboration between competitors is now being used as a best-practice example of how, with support and encouragement by local government and emergency management agencies, highly "vulnerable" groups can become more resilient and self-reliant (Aged Care Queensland, 2011).

The "All Hazards, All Agencies, All People" Approach

Building truly resilient communities requires "…a fundamental expansion from traditional approaches which emphasise physical capacity building and material disaster relief, to longer-term social capacity building" (Morton and Laurie, 2013). One way to integrate long-term social capacity building into the current emergency management model

FIGURE 3-3 The "all hazards, all agencies, all people" approach to emergency management.

is to introduce a third prong to the "all hazards, all agencies" approach—an "all people" approach, shown conceptually in Fig. 3-3. The introduction of the "all people" approach creates the context for a more holistic understanding of community disaster resilience and places a strong focus on shared responsibility.

Community disaster resilience is a critical strategy for disaster readiness. Building and enhancing community disaster resilience must be inclusive, taking into consideration the needs of the whole of community.

> *Unlike many stressors, disasters happen to entire communities. Members are exposed together and must recover together. At a minimum, if their aim is to build collective resilience, communities must develop economic resources, reduce risk and resource inequities, and attend conscientiously to their areas of greatest social vulnerability. They*

> *must engage local people in every step of the mitigation process, create organizational linkages and relationships in advance of disasters, and boost and protect naturally occurring social supports. They must plan—but also plan for not having a plan, which means that community organizations must appreciate flexibility, develop decision-making skills, and cultivate trusted sources of information... In a nutshell, disaster readiness is about social change.*
>
> *Norris et al. (2008).*

The introduction of a third "all people" approach addresses recommendations "drawn from previous disasters which indicate that the weakest link in many risk management strategies has been the lack of involvement from the local people" (Hebert, 2014). Encompassed in this "all people" approach are all the activities that individuals take in becoming disaster prepared and in looking after one another in times of emergencies, as well as the activities that governments and emergency agencies collaborate on with communities. The two new areas of overlap which appear as a result of the introduction of an "all people" approach in this model are: "supported community self-reliance" and "collaborative community resilience building." These emerge as the key areas where government and emergency management agencies focus their energy and resources in order to develop strategies for disaster resilience building. If this is achieved, emerging at the center of the diagram where all three approaches overlap is "community disaster resilience"—the outcome of an integrated "all people, all hazards, all agencies" approach.

This approach provides a model for thinking about how people can become an integral part of the existing model for emergency management in order to achieve the goal of community disaster resilience. It acknowledges that people play an equally important role as government agencies in emergency management, and that in reality they share the responsibility for disaster risk reduction and disaster resilience.

Assessing Community Disaster Resilience

In order to develop and implement strategies to achieve the objectives of community disaster resilience within any given community, it is necessary to be able to "map" and evaluate existing levels of community disaster resilience. This involves taking stock of social, geographic, built, and environmental assets as well as taking a comprehensive look at the hazards and challenges the community faces. As part of this mapping process, it is critical to collect feedback from the community (geographic or otherwise) and identify where the gaps and barriers are in the existing approach to emergency management. Based on the data collected, it becomes possible to develop and then evaluate targeted programs and initiatives that build community disaster resilience. The following case study provides an example of a longitudinal study of low-income parents in New Orleans, the findings of which have been used to make a range of policy recommendations and have given researchers valuable insights into what makes some individuals more resilient than others.

Case Study: The RISK Project, New Orleans, Louisiana, United States

The Resilience in Survivors of Katrina Project ("RISK") began as a longitudinal study of 1019 low-income parents who lived in New Orleans in 2003. Prior to Hurricane Katrina the study measured participants' economic status, social ties, and mental and physical health. Although Hurricane Katrina disrupted the research in August 2005, it provided an extremely rare opportunity to study the consequences of a disaster for the lives of vulnerable individuals and their families (see Fig. 3-4). Following Hurricane Katrina, two follow-up surveys and two rounds of in-depth qualitative interviews were conducted, which resulted in over 29 published papers (Waters et al., 2012). These findings have helped evaluate the impacts of natural disasters on low-income parents and have subsequently been used to inform policy decisions around community resilience building programs for these particular communities. This project has also highlighted the importance of longitudinal studies of vulnerable populations, particularly in disaster at risk communities, as a way of assessing and evaluating the effectiveness of disaster response and recovery efforts.

FIGURE 3-4 New Orleans, La., September 3, 2005—Evacuees and patients arrive at New Orleans airport where FEMA's Disaster Medical Assistance Teams have set up operations. *Photo: Michael Rieger/FEMA.*

Until recently there was "no published validated tool that communities could easily use to assess their resilience in preparing for an emergency event at the community level, rather than the individual level"(Arbon et al., 2012). However, several toolkits have now been developed to help communities assess their own resilience and to develop strategies for building and enhancing it. These include:

- "Community Resilience Manual," Canadian Center for Community Renewal, Canada (Colussi and Rowcliffe, 2000)
- "Communities Advancing Resilience Toolkit—CART," Terrorism and Disaster Center at the University of Oklahoma Health Sciences Center, United States (Pfefferbaum et al., 2011)

- "Community Resilience: Learn and Tell Toolkit," RAND Corporation (Towe et al., 2015)
- "Exploring Resilience Toolkit," Carnegie UK Trust, United Kingdom (Wilding, 2011)
- "Community Disaster Resilience Scorecard Toolkit," Torrens Resilience Institute, The Australian Government, Australia (Torrens, 2012)

All these toolkits are freely available online and are designed to empower communities to take ownership of their own disaster resilience, in an acknowledgment that sustainable community disaster resilience is an outcome of grassroots movements, not top-down decision-making. These toolkits all share a strong focus on asset-based community development approaches which demonstrate how people can use their resources to focus on a community's strengths and abilities rather than their vulnerabilities (Moser, 2007).

To establish an accurate picture of a community's disaster resilience, it is important to work within the community itself throughout the assessment process as opposed to relying solely on outsiders to drive the inquiry process. A "participatory action" methodology provides a best-practice framework for undertaking this kind of community–researcher collaboration, and also enables the coproduction of resilience outcomes. The experience itself can be "a basis of knowing and that experiential learning can lead to legitimate forms of knowledge that influences practice" (Baum et al., 2006). The use of this type of methodology supports communities to take ownership of their own agendas and ensure that the values of diversity and inclusion are integrated into the process itself; this enables a partnership within the communities in a manner that is more likely to represent the diversity within communities and lead to actions of change that are conducted "with people, not on them" (Wilding, 2011).

Supported Community Self-Reliance

The more communities "do" for themselves, the better. With the right information and support, it is possible to empower communities to build high levels of self-reliance and self-organization alongside the other collaborative practices (information and resource sharing, collective action and advocacy, etc.) which are the key traits of a resilient community as shown in Fig. 3-5.

> *Community-based disaster preparedness and mitigation activities are found to be the most effective ways of reducing disaster vulnerability. The first line of disaster response is at the individual and the local levels, where simple planning and preparedness measures can substantially reduce the impacts of natural hazards.*
>
> *Hebert (2014).*

However, despite this reality, many governments and emergency management agencies are reluctant to include the communities in their mitigation, preparation, response, and recovery activities, in part because of the perception of risks and liabilities.

The challenge to attaining such high levels of community self-reliance is achieving the sophisticated level of grassroots leadership with the adequate levels of autonomy and

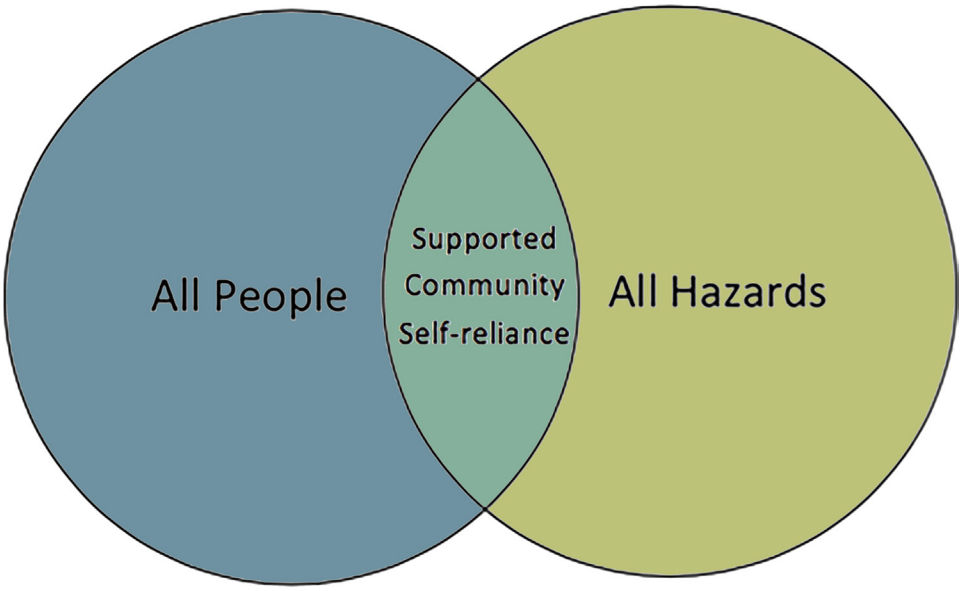

FIGURE 3-5 Supported community self reliance.

support necessary to make decisions and take collective action. Accurate and timely access to information and communication is one of the key elements that enables communities and their grassroots leaders to make informed decisions. Often in the event of natural disasters, accurate and timely information is difficult to access as a result of a lack of/or damage to infrastructure. This leaves many communities relying on information attained by word of mouth and/or from media outlets, both of which can often be ill informed. A lack of accurate and timely information at a local grassroots level before/during/after a natural disaster has repeatedly proven to have catastrophic consequences and be the source of great conflict and trauma post disaster. For this reason it is an important area in which to invest as part of mitigation and preparation activities, not only in terms of improving infrastructure, but in order to establish two-way communication pathways from the community to agencies and from agencies to the community. There are many challenges to achieving this, particularly in highly transient communities, where there is a lack of sufficient dedicated emergency management resources and agencies, or in countries with inadequate communications infrastructure, or where there is little trust between communities and authorities.

Supported community self-reliance requires governments and emergency management agencies to work together with communities, not as a replacement for the roles that government and NGOs play, but as an additional level of leadership, coordination, and asset mobilization. Depending on the community and the types of threats it faces, the type of support needed will also vary. However, support with information, education, and perhaps low levels of financial assistance provides local groups and organizations with the opportunity to take on locally-specific resilience-building activities.

The Role of Nongovernment Organizations in Community Disaster Resilience

NGOs represent a large and well-connected group of professionals who are embedded in communities and who are often better suited for reaching out to those who are at greatest risk during an emergency. The private sector, which includes both for-profit and nonprofit organizations, represents the majority of resources, assets, skills, and local expertise as well as the leadership capacity of a community. Finding strategies to increase cooperation and collaboration with the private sector across each phase of emergency management, as well as empowering them to integrate community resilience building into their core business, is an impactful and cost-effective strategy for building and enhancing community disaster resilience. The following case study illustrates the impact small local nonprofit organizations like neighborhood centers can have for enhancing local community disaster resilience.

Case Study: Emerald Community House, Australia

Emerald is a community of almost 6000 people located at the foothills of the Dandenong Ranges southeast of Melbourne, Australia. On February 16, 1983, a date now known as Ash Wednesday, Victoria experienced its worst bushfires since the Black Friday fires of 1935. Although Emerald was not directly affected by the Ash Wednesday fires, the neighboring community of Cockatoo was severely affected, with 6 fatalities, 1800 ha (4448 acres) burnt, and 307 houses and other buildings destroyed (Country Fire Authority, 1983). Emerald Community House (ECH) is a local neighborhood center which played a small role in the recovery effort in Emerald following the Ash Wednesday fires (Department of Premier and Cabinet, 2003).

Twenty years later in 2003, following a prolonged drought, the state of Victoria once again experienced severe firestorms, which burnt 1.3 million hectares (3.2 million acres) of land (Department of Premier and Cabinet, 2003). The impact of this second set of fires on local townships caused ECH to reflect on their unique potential to play a more significant role in building community disaster resilience year-round. ECH started their very own "Center of Resilience" (http://www.emeraldcommunityhouse.org.au/centre-of-resilience-cor/). ECH now delivers programs that "increase dialogue, skills and vigor in their community and interweave safety, disaster preparedness and empowerment into ordinary everyday activities" (Farrow, 2014). These programs include an annual art festival (see Fig. 3-6) run with the belief that "any community that can run its own art festival can coordinate its own voluntary disaster response" (Farrow, 2014)—and a fire safety program that all parents of children enrolled in the center's childcare facility must complete. Mary Farrow, the current director of ECH writes:

> *As an incorporated association, a business and a charity, we [ECH] recognize our ability and responsibility to instigate, create, inspire, foster, underpin, embed, support, resurrect and empower our community members to do more than they thought possible sometimes with less resources—to challenge the status quo and respect their collective power as a renewable resource.*
>
> *Farrow (2014).*

Thanks to their ongoing presence in the community and their strong ties with other community groups, organizations, and local businesses, ECH is able to provide a holistic approach to building community resilience. Despite receiving little to no funding for this targeted strategy, ECH has won several significant awards for their efforts.

FIGURE 3-6 Emerald Community House PAVE festival. *Courtesy of Emerald Community House.*

Another way the nongovernment and nonprofit sector in particular can contribute to the building and enhancement of community disaster resilience is through managing spontaneous volunteering and providing year-round volunteer opportunities. Volunteering is essential to community disaster resilience, and not just for the obvious pragmatic reasons of mobilizing people for disaster response and recovery activities. In many countries, volunteers make up a large number of both the first responders and those who manage things like evacuation centers and services to help locate and reunite people following disaster events. Volunteers are also instrumental for disaster cleanup efforts, managing donations, and providing professional services to affected communities. While the individuals and communities who receive support from volunteers are benefiting, there is also evidence to suggest that the volunteers themselves are benefiting from their actions. This is because being involved in volunteering following a disaster event provides people with a sense that they are empowered (as opposed to helpless) and that they are part of a bigger community of people who, by working together, can overcome great hardship. Furthermore, building a strong culture of volunteerism in communities has been shown to be one of the most effective ways of improving a broad range of resilience indicators from social capital, community connectedness, communication networks, and active partnerships between organizations.

Volunteer efforts have traditionally been coordinated by government or specialized emergency response agencies. However, new technologies and social media are changing the ways in which individuals and communities are being mobilized in response to natural

disasters. The following case study tells how the Christchurch "Student Volunteer Army" (SVA) emerged in New Zealand thanks to social media and the initiative of the city's young people.

Case Study—The Christchurch Student Volunteer Army (SVA), New Zealand

On September 4, 2010, Christchurch New Zealand was struck by a devastating 7.1 magnitude earthquake. Immediately following this unprecedented disaster, the "Student Volunteer Army" (SVA) was formed by a group of young local university students (see Fig. 3-7). The work of the SVA has since become recognized across the globe, and they have been recipients of the White House "Champions of Change" award. However, looking back, SVA started very simply as a Facebook event which provided a platform where anyone could put their hand up to volunteer in the cleanup efforts. This initiative quickly grew and evolved into a method for a community of young people to self-organize their own spontaneous volunteer effort. During the immediate response alone, the SVA cleared over 65,000 tons of liquefaction from low-risk areas thanks to the efforts of over 2500 students who SVA provided with safe and organized volunteer placement, transport, food, and support.

Unfortunately, the work of SVA was not yet over. On February 22, 2011, Christchurch was once again struck, this time by a 6.3 earthquake that caused far greater damage to the city. The disaster claimed close to 200 lives, and thousands of homes and businesses were destroyed. Three and a half years later, 80% of the buildings in the city center have been demolished. More than 7000 private residential properties and hundreds of hectares of land have been deemed unsafe for rebuilding and were subsequently purchased by the central government. The SVA remobilized for the second time, allowing 11,000 spontaneous volunteers to self-mobilize and self-allocate roles. While the central task was the removal of 450,000 tons of liquefaction from properties, a strong focus was put on the well-being of residents. SVA did this by showing a presence in the streets, offering everything from meals, clean water, and guidance to professional assistance.

FIGURE 3-7 The Christchurch Student Volunteer Army. http://www.ucsva.org/history/.

Initially, the core leaders of SVA faced considerable challenges in getting the operation mobilized, reflecting that interfacing with the emergency management sector and authorities was especially difficult. Understandably, officials had concerns surrounding volunteer health and safety issues as well as questions about the intentions of a group that had emerged as a leaderless and unstructured group of individuals in a postdisaster context. At one point, some coordination resources were allocated from these official bodies, resulting in a dramatic culture shift within SVA and the subsequent loss of many volunteers. SVA attribute this to the additional hurdles and imposed coordination from outside the group which ended up considerably impeding productivity. SVA were ultimately able to regain leadership and the ability to coordinate their own efforts, and quickly introduced streamlined electronic registration systems that satisfied health and safety requirements.

As a result of the scale and integrity of the operation, some operations which would otherwise have been the task of response agencies, NGOs, and local and central government departments were outsourced to SVA. This represented a considerable milestone in global emergency management, centralized services being delivered by spontaneous volunteers as part of a coherent relief operation. Unlike traditional approaches, this coherence was achieved by having a very clear common purpose: solve issues that emerged from the earthquakes in a safe and timely fashion. This "handing over" of permission to help enabled a large scale of practical response effort, but importantly also contributed greatly to the psychosocial well-being of volunteers and affected residents alike.

Collaborative Community Disaster Resilience Building

Disaster response begins at the lowest levels of government and ideally is controlled at a local level. The community itself has an important role to play as part of this local level response to emergencies, and community members themselves are frequently true first responders. For this reason the local community must be involved with and included in disaster response planning as well as at all other phases of disaster management. This can be achieved by taking an "all people, all agencies" approach to ensure that communities and agencies work collaboratively to build community disaster resilience. This collaborative action should involve cross-sector engagement and be inclusive of the diverse groups and levels of ability within society. This collaboration is illustrated graphically in Fig. 3-8.

Community Engagement

To achieve the goal of community disaster resilience, government and emergency management agencies need to actively engage with communities in order to cocreate programs and policies that build social capital and empower communities to take charge of their own disaster resilience. However, emergency management agencies attempting to engage communities in building community disaster resilience face many challenges

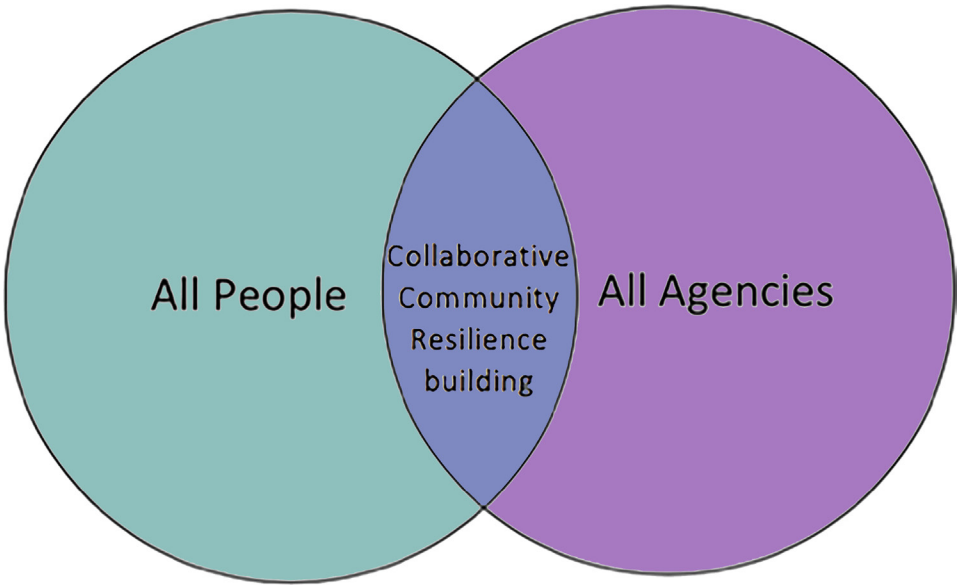

FIGURE 3-8 Collaborative community resilience building.

including: limited capacity, limited resources, lack of support or interest from communities themselves, and a lack of identified or appropriately trained community engagement officers. Furthermore, there are still high levels of government mistrust in some communities. The resulting active condemnation of governments regarding issues of disaster management works to further undermine people's confidence in how they are being represented by their government (Fitzpatrick and Molloy, 2014).

Worldwide, the majority of community engagement projects developed and delivered by governments or emergency management agencies focus on encouraging individuals and households to improve their individual level of disaster preparedness. With this goal in mind, most agencies focus on community education programming and on providing educational resources including flyers, refrigerator magnets, information booklets, and planning guides such as the FEMA "Prepare for Emergencies Now: Information to Get Ready" (FEMA, 2011) and the Red Cross "Emergency REDiPlan" (Australian Red Cross, 2014). While this information is critical for getting individuals to be adequately prepared for emergencies, these types of campaigns only address a small part of what is necessary in order to achieve community disaster resilience as illustrated in the "all hazards, all agencies, all people" framework.

Community engagement is a complex discipline in its own right, and a powerful tool for bringing about the necessary environmental and behavioral changes in communities that result in positive long-term community health and resilience outcomes (CTSA, 2011), and can have significant public impact as a result of how successfully they can build community

trust, improve communication within a community, develop partnerships, mobilize people/resources, and influence systems, serving as a catalyst for changing policies and resulting in lasting collaborations (CTSA, 2011). While community engagement often sits outside the core business of emergency management agencies, particularly response agencies, the "all hazards, all agencies, all people" model is predicated on the idea that agencies must work with communities in order to achieve community disaster resilience.

There are different levels to which communities can be engaged, and these are appropriate at different times depending on the goals, time frames, resources, and levels of concern in the decision to be made (IAP2, 2013). The International Association for Public Participation (IAP2) is a global initiative that promotes community engagement. The IAP2's Public Participation Spectrum, as detailed in Table 3-1, is designed to:

> *assist with the selection of the level of participation that defines the public's role in any community engagement program… and most importantly, the Spectrum sets out the promise being made to the public at each participation level.*
>
> *IAP2 (2013).*

The further along this spectrum toward empowerment, the more social capital is built within the engaged community and the higher the likelihood of projects and initiatives being carried forward in the long term. However, it is not always feasible or appropriate to do so. Sometimes, due to pressing time issues or limited access to resources, it is not feasible to hand over decision-making power to the community. However, a lack of agency and decision-making power for stakeholders actually depletes the social capital of individuals and communities. Therefore, whenever possible it is critical to ensure that individuals and communities feel engaged and empowered to take active roles in the decision-making processes directly affecting their lives.

One practical way to approach community engagement is to partner with nongovernment and nonprofit organizations that are:

> *ideally placed for promoting the messages of disaster management and building resilience… [they] have an enduring and trusted presence in and with the community and already engage a large majority of those communities that are commonly considered to be most vulnerable to disasters.*
>
> *Fitzpatrick and Molloy (2014).*

The other significant benefit of working with nonprofit community organizations on disaster resilience building programs is that they can act as a legally recognizable platform through which the "community" can make decisions and take action. Without such representation it is extremely difficult to develop a policy that advocates for shared responsibility, as communities cannot be directly delegated any responsibility or represent themselves within a legally binding framework (Fitzpatrick and Molloy, 2014).

Table 3-1 Public Participation Spectrum

Increasing Level of Public Impact

	Inform	Consult	Involve	Collaborate	Empower
Public Participation Goal	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the public.
Promised to the Public	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision. We will seek your feedback on drafts and proposals.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will work together with you to formulate solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
Examples	• fact sheets • websites • open houses	• public comment • focus groups • surveys • public meetings	• workshops • deliberate polling	• citizen advocate committees • consensus-building • participatory decision-making	• citizen juries • ballots • delegated decisions

International Association for Public Participation (IAP2), 2013. Adapted from IAP2'S Public Participation Spectrum. International Association for Public Participation. Retrieved June, 2, 2014. http://www.iap2.org.au/resources/iap2s-public-participation-spectrum.

Case Study—Volunteering Queensland's Natural Disaster Resilience Leadership Project, Australia

Queensland, Australia is twice as likely to experience natural disaster events as any other state in Australia. In 2010 the Natural Disaster Resilience Fund, a funding program for emergency management activities funded by state and federal government, was opened to NGOs for the first time. Volunteering Queensland, an incorporated nonprofit organization which acts as the state peak body for volunteering, was successful in its application to deliver a suite of six separate but related projects with a focus on building community resilience to natural disasters across the state. The cornerstone of the Step Up Program was a strategy to enable communities to overcome the complex myriad of intertwining issues inhibiting community resilience by empowering a diverse range of community stakeholders with the necessary knowledge, tools, and resources to build community self-reliance. The six projects that made up the Step Up Program include:

1. Emergency Volunteering Online Portal
2. Business Roundtable Extend
3. Youth Communication and Resilience Project
4. Natural Disaster Resilience Leadership Project
5. Aboriginal and Torres Strait Islander Resilience Project
6. Emergency Volunteering Community Workshop series

Each project provided tailored information, resources, pathways to engagement, and support mechanisms for individuals, business owners, community leaders, young people, and Aboriginal and Torres Strait Islander communities.

Of these six projects, the Natural Disaster Resilience Leadership Project (see Fig. 3-9) stands out as a community engagement project aimed specifically at empowering local

FIGURE 3-9 Volunteering Queensland Natural Disaster Resilience Leadership Project. *Courtesy of Volunteering Queensland.*

Continued

Case Study—Volunteering Queensland's Natural Disaster Resilience Leadership Project, Australia—cont'd

communities to take a more active role in local decision-making and in developing and implementing action plans to build community disaster resilience. Designed as a four-day experiential capacity-building workshop, this project targeted grassroots community leaders from across different sectors within the community. Delivered in over 15 different communities over 4 years, this project brought between 15 and 35 community leaders together in order to facilitate the creation of individual and collaborative "action plans" for increasing community resilience and disaster preparedness within their homes/workplaces/community. The topics covered included important information about local disaster management arrangements from the appropriate agencies, the emotional impacts of disasters, effective community leadership, asset mapping, the importance of resilient local economies, building social capital, and project planning. The key outcome of the project was that every participant spent time developing a personal or group action plan designed to build community disaster resilience which they would then go on to implement. As a result of this project, hundreds of community disaster resilience building projects occurred across the Queensland and interstate as well. Examples of some of the action plans developed during this project include:

- Individuals committing to completing their own preparedness plans and putting together stay/go kits with family as well as encouraging friends, neighbors and coworkers to do the same
- Community wellness days and education campaigns run by local community organizations with the support of local councils and emergency management agencies
- Community art recovery projects run by local artists
- Volunteer recruitment that engages in more dynamic, interactive and engaging ways such as family fun days and public art/music performances
- Establishment of emergency coordination committees and resilience leaders networks which work with local councils and agencies to relay information out/back from the community
- Aged and Disability support providers pledging to work with their patrons to increase their preparedness
- Development of a youth leadership project which incorporates elements of disaster risk reduction and personal preparedness
- Several initiatives that host disaster preparedness themed street parties
- Thank-you events for volunteers and emergency service staff involved in response and recovery as a strategy to encourage networking and collaboration across different agencies
- Interagency training days
- Local chamber of commerce involvement in business continuity programs designed to help small local businesses prepare and mitigate for disaster

All of these action plans were initiated by the participants of the Resilience Leadership Workshop and were delivered by community members or community organizations with little to no financial support; however, many of these relied on in-kind support and expertise from

local agencies. Key to the success of this program was Volunteering Queensland's ability to tap into its preexisting and well-established ties across various sectors and within communities. What projects such as this teach us is that "governments alone cannot empower communities; local leaders need to work with their communities and take action to better understand the risks their communities face so choices and decisions are appropriately informed" (Council of Australian Governments, 2011).

Community Disaster Resilience—Culture and the Arts

Culture and the arts play a critical role in a resilient community. They are an expression and celebration of a community's unique character and are vital for capturing and sharing local stories, local history, and local knowledge. A strong local arts and culture sector is indicative that a community has the creativity and flexibility necessary for complex problem solving and adaption to change. Additionally, connecting with communities through the arts and culture is one of the most impactful and effective strategies for sustainable community engagement and community resilience building efforts.

Posttraumatic Growth

Winston S. Churchill has been quoted, "Never let a good crisis go to waste," and although attribution of this quote is still debated, the phrase has entered our political psyche and presents us with a challenge that is particularly pertinent in emergency management. Disasters often present communities with a unique opportunity to pause, take stock, and reconsider what it is they truly value. It is well documented that post disaster, many individuals who experience trauma also experience posttraumatic growth, which is "subjective positive psychological changes following, and because of, a traumatic event…" (Chan and Rhodes, 2013). Posttraumatic growth encompasses perceived changes in self, interpersonal relationships, outlook on life, spirituality, and new possibilities (Tedeschi and Calhoun, 1996), and "may occur when adaptive interpretations and coping strategies are deployed" (Chan and Rhodes, 2013). Similarly, a community may undergo positive transformational growth following a traumatic disaster event, leading to increased social and cultural capital among its people, higher level of community competence and political influence, and even improved economic development. What is necessary in order to ensure that this is achieved is: (a) community resilience, (b) the leadership capacity to recognize the opportunities for growth that disasters present, and (c) the political will to address the adaptive challenges which underlie ongoing issues faced by that community rather than just providing "Band-Aid" solutions to the symptoms caused by these issues (Heifitz et al., 2009).

Case Study—Greensburg, Kansas, United States

One town that has taken on this challenge of never letting a good crisis go to waste is Greensburg, Kansas, a rural town which at 9:45 pm on May 4, 2007, was devastated by an EF5 tornado (see Fig. 3-10). Only days after the storm, the community came together in order to discuss the opportunity this disaster had presented them to totally transform their town. Rather than quickly moving to restore the damage, the community decided to seize the opportunity to build better and in a way that would better reflect the values of the community. Greensburg chose to become a model of the thriving "green town" of the future, focusing their energy around addressing issues of sustainability and toward achieving community resilience. "Greensburg GreenTown" a grassroots community-based organization, was established in order to provide the community with a body to work side by side with city and county officials, business owners, and local residents to incorporate sustainable principles into their rebuilding process. Since the rebuilding, shown in Fig. 3-11 "Greensburg GreenTown," has served as an educational resource for the community, a conduit through which donations can be distributed, and a representative to those outside the community who are interested in the Green Initiative. GreenTown continues to work on projects and to spread the idea of sustainable disaster recovery locally, nationally, and globally by working closely with other disaster-affected communities who are also looking to seize the opportunity to build back more sustainably (Greensburg, 2013).

FIGURE 3-10 Greensburg, Kansas, May 16, 2007, 12 days after it was hit by an EF5 tornado. *Photo on left by Greg Henshall/FEMA.*

FIGURE 3-11 Greensburg, Kansas, June 29, 2011. A green community model. *Photo on right by Steve Zumwalt FEMA.*

Conclusion

Resilience in social–ecological systems requires diversity, modularity, and tightness of feedback (Walker and Salt, 2006). It includes a broad set of indicators including: diversity of skills and ideas, connectedness, two-way exchanges of information, openness/transparency, accountability, and access to diverse resources (human and material). It requires organizational checks and balances which are critical for ensuring important issues are not left unaddressed. For resilience to occur there must also be a:

> *...responsibility and authority that match the scale and location of challenges and opportunities and lead to capacity for early detection and quick responses. Unfortunately, many traditional approaches to policy development and implementation either do not encourage these factors or actively erode them.*
>
> *Cork (2010).*

In today's globalized world, ensuring health security requires recognition of the interconnected nature of global systems. In acknowledging this, we must tackle disaster risk reduction on a global scale through collaborative international action, for a disaster

anywhere can have direct negative outcome for many other communities around the globe. This fact highlights the importance of investing in the building of resilient societies and in improving international collaborative efforts for disaster risk reduction and response.

Resilient communities have several key similarities. They are composed of healthy people with access to healthcare. Those individuals, families, and communities have an understanding of critical steps to take during an emergency or disaster. They also have the resources to accomplish those steps. In addition, they care for others routinely and during emergencies. (Morton and Lurie, 2013). Ideally, "communities that possess resilience characteristics can also arrive on the other side of a crisis in a stronger position than pre-event" (Arbo et al., 2012). Building resilience is neither a quick fix nor a process that can be achieved through top-down pressure alone. It requires a holistic approach to understanding and supporting community as well as an "all hazards, all agencies, all people" approach to disaster risk reduction.

There is a limit to what resilient communities can achieve on their own—ultimately a big enough disaster or a combination of disruptions within a short space of time will devastate a community's capacity to respond and recover from such adversity. Therefore, resilience building should not be seen as an opportunity to outsource or shift the responsibility of government and agencies onto communities, or to reduce the level of support (financial, material, and in kind) that communities receive. There is widespread evidence that investing in disaster mitigation and preparedness efforts not only saves lives but also significantly decreases the costs of subsequent response and recovery efforts (Kelman and Shreve, 2013). This is an outcome of the significant disaster risk reduction and increased levels of individual and organizational preparedness achieved through successful community disaster resilience building efforts. With this in mind, it is critical for government and emergency management agencies to support, collaborate with, and resource grassroots community engagement in resilience-building activities.

Finally, it is important to recognize that disasters create unique opportunities for positive growth and act as one of the most powerful catalysts for sudden increases in community cohesion, collaboration, and connection based around shared human values and a shared vision for the future. If disasters are seen as opportunities to mobilize people and make the necessary changes, then communities can increase their resilience and become more sustainable into the future.

Websites

United Nations Office for Disaster Risk Reduction (UNISDR), Making Cities Resilient: 'My City Is Getting Ready!' Campaign. http://www.unisdr.org/campaign/resilientcities/.

UK Department for International Development, Defining Disaster Resilience: A DFID Approach Paper. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/186874/defining-disaster-resilience-approach-paper.pdf.

U.S. Department of Homeland Security, Building a Resilient Nation. http://www.dhs.gov/building-resilient-nation.

U.S. Federal Emergency Management Agency, Crisis Response and Disaster Resilience 2030: Forging Strategic Action in an Age of Uncertainty. http://www.fema.gov/media-library-data/20130726-1816-25045-5167/sfi_report_13.jan.2012_final.docx.pdf.

National Research Council (US), Disaster Resilience: A National Imperative, 2012. http://www.nap.edu/catalog/13457/disaster-resilience-a-national-imperative.

National Academy of Sciences (US), Resilient America Roundtable. http://sites.nationalacademies.org/PGA/resilientamerica/.

References

Aged Care Queensland, 2011. Aged Care Queensland Disaster Management Report 2011 Aged Care Qld Incorporated Retrieved April 19, 2014. http://www.qld.lasa.asn.au/sites/default/files/disastermanagementreport2011_0.pdf.

Arbon, P., Gebbie, K., Cusack, L., Perera, S., Verdonk, S., 2012. Developing a Model and Tool to Measure Community Disaster Resilience: Final Report October 2012. TORRENS Resilience Institute. Retrieved September 3, 2014. http://static.placestories.com/pool/doc/38/31/11/667iz-16372d31e23973f8ed918a6c1c.pdf.

Australian Red Cross, 2014. Emergency REDiPlan. Emergency Services: Resources. Retrieved June, 2, 2014. http://www.redcross.org.au/emergency-resources.aspx.

Baum, F., MacDougall, C., Smith, D., October 2006. Participatory action research. Journal of Epidemiology and Community Health, BMJ Group 60 (10), 854–857. http://dx.doi.org/10.1136/jech.2004.028662 PMCID:PMC2566051.

Chan, C.S., Rhodes, J.E., April 2013. Religious coping, posttraumatic stress, psychological distress, and posttraumatic growth among female survivors four years after Hurricane katrina. J. Trauma. Stress 26, 257–265. Retrieved July 2, 2014. http://www.riskproject.org/wp-content/uploads/2014/02/Chan-Rhodes-religion-2013.pdf.

Chandra, A., Acosta, J., Meredith, L.S., Sanches, K., Stern, S., Uscher-Pines, L., Williams, M., Yeung, D., 2010. Understanding Community Resilience in the Context of National Health Security: A Literature Review. Retrieved April 17, 2014. http://www.rand.org/content/dam/rand/pubs/working_papers/2010/RAND_WR737.pdf.

Clinical and Translational Science Awards Consortium (CTSA), 2011. CTSA Community Engagement Key Function Committee Task Force on the Principles of Community Engagement, second ed. Clinical and Translational Science Awards Consortium's Community Engagement Key Function Committee. NIH Publication No. 11–7782 Printed June 2011. Retrieved April 7, 2014. http://www.cdc.gov/phppo/pce/part1.htm.

Colussi, M., Rowcliffe, P., 2000. Community Resilience Manual: A Resource for Rural Recovery & Renewal. Canadian Centre for Community Renewal, Canada. http://communityrenewal.ca/community-resilience-manual.

Cork, S., Walker, B., Buckley, R., 2008. How Resilient Is Australia? Australia 21 Report. Retrieved June 8, 2014. http://www.emergencyvolunteering.com.au/home/Resource%20Library/How_Resilient_is_Australia.pdf.

Cork, S., 2010. Resilience and Transformation: Preparing Australia for Uncertain Futures. CSIRO Publishing, Collingwood.

Council of Australian Governments (COAG), 2009. National Strategy for Disaster Resilience: Building Our Nation's Resilience to Disasters. Retrieved July 17, 2014. https://www.coag.gov.au/sites/default/files/national_strategy_disaster_resilience.pdf.

Council of Australian Governments, 2011. National Strategy for Resilience: Building Out Nation's Resilience to Disaster. Attorney General's Department, Bardon. Retrieved June 9, 2014. http://www.coag.gov.au/node/81.

Country Fire Authority, 1983. The Major Fires Originating 16th February, 1983. Victoria Country Fire Authority. Vaughan Printing Pty. Ltd, East Kew.

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J., 2008. Community and Regional Resilience: Perspectives from Hazards, Disasters, and Emergency Management. Retrieved June 13, 2014. http://www.resilientus.org/wp-content/uploads/2013/03/FINAL_CUTTER_9-25-08_1223482309.pdf.

Department of Homeland Security, U.S. (DHS), 2011. National Preparedness Goal. Retrieved June 5, 2014. http://www.fema.gov/national-preparedness-goal.

Department of Premier and Cabinet, 2003. Report of the Inquiry into the 2002–2003 Victorian Bushfires. State Government of Victoria. ISBN: 0731114884. Retrieved July 15, 2014. http://www.royalcommission.vic.gov.au/getdoc/e9af877b-fae7-4dd1-99dc-d696fa2c8c04/INF.018.002.0001.pdf.

Douglas, B., 2010. Why some people are more resilient to health problems than others? In: Cork, S. (Ed.), Resilience and Transformation: Preparing Australia for Uncertain Futures. CSIRO Publishing, Collingwood.

Farrow, M., 2014. Chairman, Committee of Management Emerald Community House. Email Correspondence May 9, 2014.

Federal Emergency Management Agency (FEMA), 2011. National Preparedness Goal. Retrieved April 23, 2014. http://www.fema.gov/national-preparedness-goal.

Fitzpatrick, T., Molloy, J., 2014. The role of NGOs in building sustainable community resilience. Int. J. Disaster Resilience Built Environ.1759-5908 5 (3). Retrieved June 29, 2014. http://www.emeraldinsight.com/journal/ijdrbe.

Gibson and Tarrant, 2010. Aust. J. Emerg. Manage. 25 (2) April 2010.

Greensburg, 2013. Green Town History. Available at: http://www.greensburggreentown.org/history/.

Hebert, S., 2014. Managing community participation in support of disaster resilience. In: IAEM Bulletin June 2014, pp. 9–10.

Heifetz, R.A., Grashow, A., Linsky, M., 2009. The Practice of Adaptive Leadership: Tools and Tactics for Changing Your Organization and the World. Harvard Business Review Press.

Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters Retrieved May 11, 2014. http://www.unisdr.org/we/coordinate/hfa.

International Association for Public Participation (IAP2), 2013. IAP2'S Public Participation Spectrum. International Association for Public Participation. Retrieved June, 2, 2014. http://www.iap2.org.au/resources/iap2s-public-participation-spectrum.

International Strategy for Disaster Reduction, 2005. Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters. In: World Conference on Disaster Reduction A/CONF.206/6. Retrieved June 2, 2014. http://www.unisdr.org/2005/wcdr/intergover/official-doc/L-docs/Hyogo-framework-for-action-english.pdf.

Kelman, I., Shreve, C.M., 2013. Disaster Mitigation Saves. Version 12, June 13, 2013 (Version 1 was October 30, 2002). Downloaded from: http://www.ilankelman.org/miscellany/MitigationSaves.doc.

McAslan, A., 2010. The Concept of Resilience: Understanding its Origins, Meaning and Utility. published March 14, 2010 TORRENS Resilience Institute, p. 11. Retrieved August 5, 2014. http://www.torrensresilience.org/images/pdfs/resilience%20origins%20and%20utility.pdf.

Morton, M.J., Lurie, N., July 2013. Am. J. Public Health Editorial 103 (7), 1159. Retrieved June 12, 2014. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3682626/pdf/AJPH.2013.301354.pdf.

Moser, C., 2007. Reducing Global Poverty: The Cast for Asset Accumulation. Brookings Institution Press, Washington DC.

Norris, F.H., Stevens, S.P., Pfefferbaum, B., Wyche, K.F., Pfefferbaum, R.L., 2007. Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness. Springer Science+Business Media. Retrieved June 5, 2014. http://www.emergencyvolunteering.com.au/ACT/Resource%20Library/CR_metaphor_theory_capacities.pdf.

Norris, F.H., Stevens, S.P., Pfefferbaum, B., Wyche, K.F., Pfefferbaum, R.L., 2008. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. Am. J. Community Psychol. 41 (1–2), 127–150.

Obama, B., 2011. The White House. Presidential Policy Directive 8 (PPD-8): National Preparedness. Official Department of Homeland Security. Published January 15, 2014. Retrieved June 29, 2014. http://www.dhs.gov/presidential-policy-directive-8-national-preparedness.

Parker, R., 2010. Chapter 4: managing for resilience. In: Cork, S. (Ed.), Resilience and Transformation: Preparing Australia for Uncertain Futures. CSIRO Publishing, Collingwood, Australia.

Pfefferbaum, B.J., Reissman, D.B., Pfefferbaum, R.L., Klopm, R.W., Gurwitch, R.H., 2007. Building resilience to mass trauma events. In: Doll, L.S., Bonzo, S.E. (Eds.), Handbook of Injury and Violence Prevention. Springer Science+Business Media, New York, pp. 347–358.

Pfefferbaum, R.L., Reissman, D.B., Pfefferbaum, B., Wyche, K.F., Norris, F.H., Klamp, R.W., 2008. Factors in the development of community resilience to disasters. In: Blumenfield, M., Ursano, R.J. (Eds.), Intervention and Resilience after Mass Trauma. Cambridge University Press, Cambridge, England, pp. 49–68.

Pfefferbaum, R.L., Pfefferbaum, B., Van Horn, R.L., 2011. Communities Advancing Resilience Toolkit (CART): The CART Integrated System. Terrorism and Disaster Centre at the University of Oklahoma Health Sciences Centre, Oklahoma City, OK.

Redland City Council, 2010. Redland Aged Care Providers Group Emergency Management Arrangements: Partnering Agreement between Redland Aged Care Providers Group Facilities. http://www.qld.lasa.asn.au/sites/default/files/6_racpg_emergency_management_arrangements.docx.

Tedeschi, R.G., Calhoun, L.G., July 1996. The posttraumatic growth inventory: measuring the positive legacy of trauma. J. Trauma. Stress 9 (3), 455–471. http://dx.doi.org/10.1002/jts.2490090305.

Torrens Resilience Institute, 2012. Community Resilience Toolkit. Adelaide. Retrieved June 5, 2014. http://www.torrensresilience.org.

Towe, V., Chandra, A., Acosta, J., Chari, R., Uscher-Pines, L., Sellers, C., 2015. Community Resilience: Learn and Tell Toolkit. RAND Corporation, Santa Monica, CA. Retrieved May 10, 2015. http://www.rand.org/pubs/tools/TL163.

United Nations International Strategy for Disaster Reduction (UNISDR), 2007. Terminology. Retrieved May 25, 2014. http://www.unisdr.org/we/inform/terminology.

Walker, B., Salt, D., 2006. Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Island Press, Washington.

Waters, M., Rhodes, J., Fussell, B., 2012. The Resilience in Survivors of Katrina Project. Retrieved June 3, 2014. www.riskproject.org.

Wilding, N., 2011. Exploring Resilience in Times of Rapid Change. Fiery Spirits Community of Practice and Carnegie UK Trust . ISBN: 978-0-900259-82-1 Retrieved June 5, 2014. http://www.carnegieuktrust.org.uk/getattachment/75a9e0c4-8d75-4acb-afac-6b1cbd6f2c1e/Exploring-Community-Resilience.aspx.

4

At-Risk Populations

OBJECTIVES

- Explain why some populations are more at risk than others.
- Define functional and physiological risks for vulnerabilities during a disaster.
- Illustrate current US laws requiring planning for at-risk populations.
- Describe risk-based frameworks for identifying at-risk populations.
- Describe a hazard-based framework for identifying at-risk populations.
- Explain how to use a hazard-based framework for planning the delivery of needed resources.
- Describe when to use a risk-based framework and/or a hazard-based framework while planning.
- Describe specific resources which may need to be delivered to people with functional needs.
- Identify resources within a community to assess who may have access and functional needs.
- List response components for at-risk populations.

As a community or government plans for delivery of public health resources to at-risk populations during and after a disaster, it must first define the at-risk populations and identify what resources may be needed before planning the acquisition, allocation, and delivery of those resources. Public health emergency scenarios present unique aspects to defining who is at risk. The terms "vulnerable," "at-risk," and "special needs" are often used interchangeably by many organizations, making it difficult to apply guidance and plan effectively for these groups. Public health emergency scenarios such as pandemics are unique. Public health concerns in other scenarios such as wild fires and earthquakes have unique components driving the need for a clear understanding of what constitutes "risk" and makes a population "vulnerable."

At-Risk Population Definitions

Access The ability to fully use and integrate into programs, services, activities, goods, facilities, privileges, advantages, or accommodations provided by a public or private (for-profit or not-for-profit) entity, any contracted entity, or entity providing emergency services, including sheltering.

Consumable medical goods or supplies Medical supplies (medications, diapers, bandages, etc.) which are ingested, injected, or applied and/or are one-time use only.

Disability A physical or mental impairment substantially limiting one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment.

Durable medical goods, equipment, or supplies Medical equipment (eg, walkers, canes, wheelchairs, etc.) used by persons with a disability to maintain their usual level of independence.

Functional needs Support enabling children and adults to maintain their usual level of independence.

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Risk A situation involving exposure to danger. For the purposes of this context, risk is a characteristic imposed on a person or community.

Vulnerability The state of being open to injury. For the purposes of this context, vulnerability is a characteristic of a person or community.

Risk-Based Frameworks

Definitions and frameworks currently used by the response community identify "at-risk," "vulnerable," and "special populations" primarily through natural disaster scenarios and rely on chronic health and disability status and healthcare access risk factor models (Jurgle, 2010). These at-risk population frameworks emphasize the ability to have access to services and to function physically. The frameworks have primarily come from federal laws and definitions used by the US. Department of Justice, the US Federal Emergency Management Agency (FEMA), and the US Department of Health and Human Services (HHS). Variations of these frameworks are currently used by the broad community of disaster response agencies, including emergency management, emergency medical systems, the fire service, and public health preparedness.

FEMA's 2013 National Response Framework places planning for at-risk populations within whole community preparedness planning, which includes individuals, families, households, communities, the private and nonprofit sectors, faith-based organizations, and local, state, tribal, territorial, and federal governments (FEMA: National Response Framework). US federal laws which established the scope and definition of at-risk populations include the Americans with Disabilities Act (ADA) of 1990 (US Public Law 110-325, 2008), Pandemic and All-Hazards Preparedness Act (PAHPA) of 2006 (US Public Law No. 109-417, 2006) and Pandemic and All-Hazards Preparedness Reauthorization Act of 2013 (US Pubic Law No. 113-5, 2013), and the Rehabilitation Act of 1973 (US Public Law No. 93-112, 1973). The ADA makes persons with disabilities a protected class requiring no discrimination in any government-provided services. According to the 2006 PAHPA, "the term 'at-risk individuals' means children, pregnant women, senior citizens and other individuals who have special needs in the event of a public health emergency, as determined by the (HHS) Secretary." The HHS Office of the Assistant Secretary for Preparedness and Response expands the definition of at-risk individuals for planning purposes.

At-risk individuals are people with access and functional needs that may interfere with their ability to access or receive medical care before, during, or after a disaster or emergency. Irrespective of specific diagnosis, status, or label, the term "access and functional needs" is a broad set of common, crosscutting, access, and function-based needs.

- **Access-based needs** require ensuring that resources are accessible to all individuals, such as social services, accommodations, information, transportation, medications to maintain health, and so on.
- **Function-based needs** refer to restrictions or limitations an individual may have that require assistance before, during, and/or after a disaster or public health emergency.

These at-risk population definitions and accompanying frameworks, which are based on an access and functional needs context, easily apply to natural disaster and contaminating event scenarios where time-sensitive direct assistance is necessary. For example, agencies needing to provide transportation during evacuation from a wildfire need to plan not only for people without their own transportation, but also for people with physical disabilities and needs requiring specialized assistance.

The Post-Katrina Emergency Management Reform Act of 2006 ensures planning, response, and recovery attention to people with disabilities and special needs. The Act also calls, within the reorganization of FEMA, for a Disability Coordinator to plan for housing needs and other services "to address the unique requirements of populations with special needs" (US Public Law No 109-295, 2006) Bea et al., 2006.

In November 2010, FEMA published its Guidance on Planning for Integration of Functional Needs Support Services in General Population Shelters. This document was developed to produce standards for accommodations of those with functional needs who seek sheltering during evacuation. FEMA not only recognizes the need to be in compliance with ADA requirements but also to maintain inclusiveness and to integrate all populations within the shelter. The complexities of making such accommodations require community assessments to determine possible demand, site inspection, and potential reengineering and planning. As an example, in preparing shelters for evacuated individuals during a wildfire, if a community risk assessment determines there are residents with visual impairments, mobility needs and power-dependent medical equipment, accommodations will need to be planned for and delivered. The shelter will need staff capable of attending to these needs, walkways with special grab rails and ramps, signage in large bold lettering and also in Braille, and adequate generators or backup batteries.

While functional needs are emphasized in much of the current risk-based planning, social and demographic attributes of a community may have a significant impact on its ability to respond and recover. Many low-income individuals in New Orleans had no vehicles in which to evacuate, means with which to prepare, nor resources for recovering. Several attempts have been made to measure vulnerability based on social determinants since this approach's introduction by Cutter et al. in 2003; Flanagan et al., 2011. The Centers for Disease Control and Prevention introduced the social vulnerability index (SVI) to guide planners in identifying those who are most vulnerable. The domains forming the basis of the SVI include:

- socioeconomic status
- household composition and disability
- minority status and language
- housing and transportation

Economically challenged populations are less likely to have resources to marginally prepare for disasters; have higher costs in replacing lost valuables; and may not have the educational level to know what to do, where to access information, and how to respond and recover. The age groups and health status of the affected community will determine not only its vulnerabilities but also its ability to recover. An unhealthy community will have

more difficulty recovering within a stressed infrastructure. Minority status and language differences will affect access to services and information. Housing infrastructure will impact risks to extreme weather conditions and environmental hazards. Transportation infrastructure will impact the ability to evacuate and access to resources for recovery. Census tract data from economic and population databases and surveys such as the Behavioral Risk Factor Surveillance System provide inputs for calculating the SVI. Uses of the tool include web-based modeling such as one provided by the University of North Carolina (see Fig. 4-1), where planners can choose the input data and calculate SVIs, then generate a map for their community to guide resource need and allocation (MacDonald et al., 2012).

Many communities develop registries of individuals with functional needs either through voluntary identification by individuals to a central registry or through a system of agencies who deliver services to clients with needs, such as home health agencies and power companies. However, these registries are difficult to maintain. With time, contact information changes, people change residences, vulnerability status changes (eg, a person who may have mobility issues due to a broken bone may not be classified as at-risk once the bone heals). These ongoing fluctuations throughout a community result in an ever-changing line listing of at-risk individuals, which necessitates vigilant upkeep by personnel to ensure its accuracy and utility. In many cases, it may be more efficient to maintain a registry of agencies with customer and client registries containing up-to-date information. Other agencies and partners may maintain information related to homebound elderly such as community block patrols.

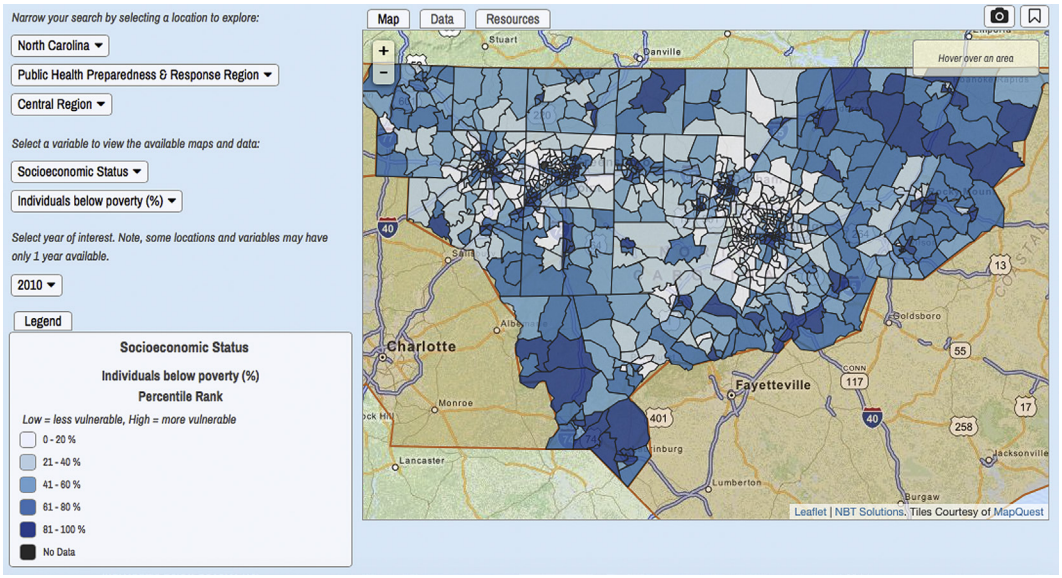

FIGURE 4-1 Socioeconomic status for the central public health preparedness region of North Carolina (accessed August 30, 2015). *From UNC vulnerable and at-risk populations resource guide:* http://www.varpguide.com/data.

However, these definitions and risk-based frameworks often create gaps for the types of preparedness, response, and recovery activities falling under the purview of public health. While disabilities and needs are assumed to be vulnerabilities through these definitions and frameworks, they do not address the nuances of hazards applying specifically to health and making a population particularly vulnerable. The frameworks may unintentionally include populations not at high risk, and more concerning, exclude populations that do in fact face higher risks during specific hazards.

In communicable disease emergencies, vulnerabilities frequently are physiological in nature and may be transient as people get sicker or better. Risk factors for complications observed during the 2009 H1N1 pandemic included preexisting health conditions such as pregnancy, chronic respiratory disease, obesity, and diabetes, as well as very young and very old age (Van Kerkhove et al., 2011). Similarly, the 2014 Ebola outbreak demonstrated high occupational risk of infection for healthcare providers.

Components of a Response

In order to address specific functional and access needs of at-risk populations, a number of categories of components should be considered. How many of these elements to plan for will be determined by the jurisdictional hazard analysis and the burden of these conditions within the population. Having contracts in place, allocation policies and procedures agreed upon, and messages preformatted allows for rapid and efficient deployment during emergencies.

- Access
- Sensory deficits
- Availability of durable and consumable medical goods
- Power supplies
- Language and cultural competency of messages
- Food services
- Intellectual and cognitive conditions
- Service animals

Access

People with mobility issues may need accommodations to evacuate and shelter. If power is not available, usual methods such as elevators and lift devices may not function, making evacuation difficult. Building facilities which subsequently provide shelter will need ramps, halls, and doorways at least 39” (1 m) wide, allowing for wheelchairs, power chairs, and crutches. Transportation provided for evacuation will need to include paratransit vehicles.

On February 26, 1993, terrorists exploded a bomb in a parking garage under the World Trade Center north tower in New York City. Six people died. The evacuation took nearly 4 hours in dark, smoky, poorly marked stairwells. Some people were stuck in elevators for 10 hours. The Port Authority made crucial improvements after that attack. The changes saved countless lives on September 11, 2001.

The Port Authority put reflective paint on stairs, railings, and stairwell doors, added bright arrows to guide people along corridors to stairway connections, and installed loudspeakers so building managers could talk to people in their offices as well as in hallways. It gave every disabled person an evacuation chair in which two husky men could carry them down stairs. One evacuation chair was used to carry a man down from the 67th floor (Cauchon, 2001).

Sensory Deficits

Visual sensory deficits can be accommodated by text-to-speech signage, television captioning, and signs in Braille. Tactile devices in buildings can assist in evacuation. After the 1993 attacks on the World Trade Center, rough tape was applied to exit doors and exit stair rails so individuals could know where they were in poor lighting conditions. Fig. 4-2 illustrates the provision of services for those who are deaf or hearing impaired.

FIGURE 4-2 FEMA Applicant Services Program Specialist Maria Gabel demonstrates an iPad set up for deaf or hearing-impaired applicants at a recovery center set up at the library. *Photo by Jocelyn Augustino courtesy of the Federal Emergency Management Agency.*

Availability of Durable and Consumable Medical Goods and Supplies

Durable medical goods such as oxygen and glucose monitoring devices may be in short supply, not only in the community but also at medical facilities because of interruption in the transportation infrastructure. Planning with suppliers and having contracts in place for emergency delivery will need to be coordinated with partner agencies (see Fig. 4-3). Decisions regarding caching and allocation across the health and medical sectors should be discussed well before the need arises. Dialysis services for patients with chronic renal failure will compete with the need for acute services in many mass casualty incidents. A plan for layered surge capacity will optimize delivery for services.

Consumable medical supplies, such as medications, will also need to be planned with pharmaceutical distributors. Most pharmacies and hospitals in the United States have only limited just-in-time inventories. Contingency plans for interruption of the transportation infrastructure will need to be considered during planning. Many pharmacy plans allow for only a 30-day supply of medication; however, those who need to evacuate or are displaced during an emergency may need a longer supply or a replacement supply if their medications are lost or destroyed. Individuals who rely on lifesaving medications should be informed of these possibilities, be instructed to have safe supplies, and be prepared for losses, especially in particular risky environments or times such as in hurricane-prone regions and extreme winter weather areas. Physicians should review emergency plans regularly with patients. Many chain pharmacies have, through electronic records, the ability to look up prior medication and can dispense emergency supplies.

FIGURE 4-3 Houston, TX, September 2, 2005—approximately 18,000 Hurricane Katrina survivors are housed in the Red Cross shelter at the Astrodome and the Reliant Center. *Photo by Andrea Booher, courtesy of the Federal Emergency Management Agency.*

Power Supplies

Individuals with power-dependent medical equipment are at risk during many emergencies. Fortunately in many disaster-prone areas, suppliers of this equipment are knowledgeable and plan with their clients for the interruption of power. This does not mean everyone has plans. Additionally, if an individual needs to evacuate or shelter-in-place for prolonged periods, power support will be needed. If the evacuation is to a shelter with limited power supply, planning for the allocation of this scarce resource will need to occur. Unfortunately, many individuals with power-dependent medical equipment find themselves transported to acute medical facilities, further stressing the healthcare infrastructure.

Language and Cultural Competency of Messages

Public messaging regarding self-protection measures should be in the languages of the community and not just the predominant language. Interpreters and translators may need to be available at congregating locations (shelters, evacuation points) in order to assist. Additionally, messages should be culturally competent in order to communicate effectively. Relying on trusted leaders in the community before the event to review preformatted common messages and then helping to deliver messages will assist in effective communication.

Food Services

Providing food during and immediately after a disaster is extremely challenging. Dietary concerns including food sensitivities and allergies, special medical diets, and cultural preferences will need to be considered in planning any emergency food supply. Not addressing these concerns could add acute illness to an already overwhelmed environment.

Intellectual and Cognitive Conditions

Mental and behavioral health services not only arise new during and after an emergency, but those with chronic ongoing conditions have unique response and recovery needs. Messaging will need to be clear, and consistent with the community's ability to comprehend and act on recommendations for self-protection. Special accommodations for support are best planned for through collaboration with caregivers and partner agencies.

Service Animals

Service animals are integral healthcare partners for an increasing number of individuals. Service animals are not limited to guide dogs. Planning for accommodations such as evacuation, sheltering, and acute veterinary care for these service animals must also be completed in advance of need.

Service Dog Central

According to the University of Arizona, 0.9% of persons with disabilities are partnered with service dogs. In 1990, Congress found that there were 43 million Americans with disabilities, suggesting there are approximately 387,000 service dogs across the United States.

Guide Dogs reports there are approximately 10,000 guide dogs (from all guide dog schools) in the field. In light of the obvious fact that guide dogs for the blind must account for more than 2.5% of the overall service dog population, the University of Arizona figure probably includes emotional support animals which are sometimes grouped with service animals, such as under the Fair Housing Act or Air Carrier Access Act. A more reasonable estimate of the number of public access (task trained) service dogs in the United States might be 100,000 to 200,000.

From http://www.servicedogcentral.org/content/.

Hazard-Based Framework

The challenge is to identify vulnerabilities in populations which may put them at risk. In order to achieve this, a framework which looks at hazards and analyzes what makes a population at risk relative to the specific hazard in a step-by-step approach may be more useful. To address these concerns, the North Carolina Department of Health and Human Services developed a framework to identify populations at risk relative to three major hazard categories: communicable disease, extreme weather and natural disasters, and contaminating events. Each of these hazard categories presents distinctive stressors for an affected community. Utilizing this framework, public health emergency planners can strategically focus planning, outreach, and response efforts on specific at-risk populations in their community.

In using this framework, the first step is to complete a jurisdictional hazard analysis identifying which hazard or type of hazard is most likely. After identifying the likely hazards, planners then identify which at-risk populations exist within the community for each hazard category. In the next three tables, examples of specific populations, which may be at increased risk because of the distinctive threats posed by the hazard, are identified.

Communicable Diseases

Examples of communicable diseases include: pandemic influenza, select bioterrorism agents, and Ebola.

Table 4-1 illustrates populations at increased risk of the threats posed by a communicable disease incident/outbreak.

Table 4-1 Communicable Diseases

At-Risk Populations	Reason for At-Risk Status
Children	Immune system is still developing in children under 2 years of age Poor independent hygiene practices (handwashing, covering coughs, nose blowing, etc.) Frequent close contact environments Fecal–oral environments and hand–oral behaviors
Pregnant Women	Hyperresponsiveness and hyporesponsiveness immunologic system Fetal impact
Elderly	Weakened immune system due to immunosenescence
Individuals with Chronic Health Conditions/ Immunocompromised	Compromised immune system either primary or secondarily induced
Individuals with Communication Challenges (undereducated, limited English proficiency, disabilities, etc.)	May be unable to read/understand public health messaging regarding preventative measures or to communicate their health needs May have difficulty communicating personal health conditions to public health or healthcare professionals
Unable to Access Medical Aid (finances, access, transportation)	Financial constraints may prevent this population from seeking/ obtaining necessary medical care
Individuals with Mental/Behavioral Health Issues	May struggle to understand public health messaging regarding preventative measures, or may not be capable of seeing/obtaining care independently
Frontline Healthcare Providers (including Medical Reserve Corps, volunteers, caregivers)	May be at risk due to the amount of exposure they encounter in the workplace
Event/Scenario-Driven Special Conditions (eg, high-density residential facilities and geographic areas with poor infection control measures)	May not have access to control measures such as clean water to bathe, personal protective equipment May not be able to limit congregate activities
Special cases	Based on specific jurisdictional hazards identified risk, can include agricultural Immunosuppressed: may be at higher risk when exposed to infectious diseases Religious or cultural beliefs impacting preventative measures or treatments

Extreme Weather and Other Natural Disasters

Extreme weather events have far-reaching health, economic, and societal consequences (McMichael et al., 1996). Weather events often disproportionally impact individuals who are medically fragile (Behr and Diaz, 2013), areas that are socially vulnerable (Cutter et al., 2003), and populations disadvantaged by low income, disability, health status, age, and limited access to information and resources (Van Zandt et al., 2011; Hunter et al., 2015). Table 4-2 illustrates potential at-risk populations during an extreme weather event or natural disaster.

Table 4-2 Extreme Weather and Other Natural Disasters

At-Risk Populations	Reason for At-Risk Status
Durable medical goods users	May be dependent on electricity May be dependent on supply chain May be dependent on technicians and/or assistants.
Elderly	May have mobility issues May be institutionalized or hospitalized May not have physiological, cognitive, and mechanical resiliency to new and stressed environments
Transient populations (eg, tourists, students, military bases)	May not be familiar with the community emergency plans and procedures (where to obtain information, evacuation routes, sheltering-in-place instructions) May not be familiar with the dangers presented by this hazard May not have access to immediate transportation in the event of evacuation
Individuals with mobility issues	May not be physically able to evacuate
Limited English-proficient and diverse cultures	May not understand emergency messaging (warnings and instructions) May not be able to communicate with locals and/or responders May not have trust in or may be fearful of government authority
Individuals with functional/access needs	May not be physically or cognitively capable of evacuating without assistance May not be able to communicate or process emergency messaging and instructions May not be able to adapt to new or temporary environments or change of structure
Institutionalized/congregated populations (eg, jails, large-scale sporting events, healthcare facilities, nursing homes, day-care centers)	May be a challenge to evacuate large groups of people safely May be a challenge to shelter a congregated population in place
Disaster response personnel	May experience burnout or disaster mental health issues that prevent them from being effective responders
Special cases	Based on specific jurisdictional hazards identified risk, can include: pet owners (may not be willing to evacuate without pets), cultural and religious beliefs/communities

Contaminating Events

Contaminating events encompassing this hazard category include chemical, biological, radiological, nuclear, and explosive incidents which threaten the health of the public. Specific examples include oil spills, nuclear disasters, and chemical explosions.

Jurisdictional hazards planners need to consider events and locations including but not limited to intentional release risks, fixed nuclear facilities, chemical production and storage facilities, agricultural processing plants, commercial farms where pesticides and fertilizers are used, major transportation routes where tankers or trains regularly carry hazardous substances through the community, etc. Table 4-3 illustrates potential at-risk populations during a contaminating event.

Table 4-3 Contaminating Events

At-Risk Populations	Reason for At-Risk Status
Individuals in immediate vicinity	People in the immediate vicinity could be at risk of toxic or fatal exposure, contamination, and/or impact.
High-risk occupational groups (ie, first responders)	First responders may not know what substances were released or the dangers of the substances released (manufacturer safety data sheets information), resulting in putting themselves in danger by nature of responding to the incident.
Pregnant women	Fetal development impact
Special cases	Based on specific incident circumstances, can include any groups from other two hazards including: Children: may be at higher risk for substances that, when released, remain close to the ground People with respiratory issues: may be particularly susceptible to both low- and high-level exposure to respiratory irritants and toxic chemicals Immunosuppressed: may be at higher risk when exposed to toxic chemicals

Once planners have identified at-risk populations within a community for each hazard category, they can then locate geographically high concentrations of these populations within a community.

Planners can strategically engage individuals, community groups, and partner agencies who routinely work with the identified at-risk populations on a regular basis in order to initiate planning and preparedness efforts specific to the hazard(s) posing a threat to these populations. The strength of working with these individuals and community groups is in the existing relationship between the partner group and members of the at-risk population. Members of these populations are more likely to identify their specific needs and existing resources. Trusted sources can begin planning with government and relief service agencies, especially in areas not previously identified. This partnership builds resilience within the at-risk population as the need to plan is fostered. Planners can take a system-of-systems approach, leveraging multiple layers of individuals and resources. Finally, in the event of an emergency, partnerships are already established.

This framework can be utilized as a multistep multilayered planning process within the cycle of preparedness, as outlined below and in Fig. 4-4:

1. *Identify potential hazards to the jurisdiction*: use the hazard risk assessment, community health survey, or jurisdictional risk assessment to determine the most likely and highest priority hazards.
2. *Enumerate and map at-risk populations*: Use the framework to determine the groups of people who will be most at risk for adverse health outcomes during the hazards identified in Step 1. Obtain quantitative, geospatial, and contextual information about identified at-risk population groups using sources such as: Census and American

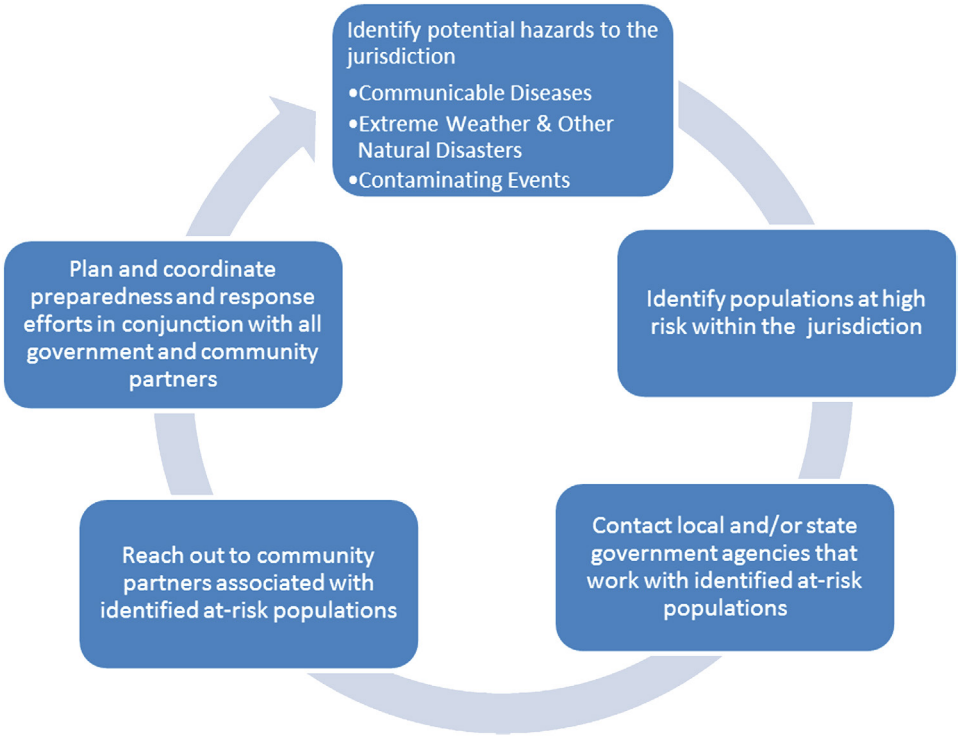

FIGURE 4-4 Suggested steps for hazard-based at-risk populations planning.

Community Survey data, state and local vital statistics, Centers for Medicare Services power dependency reports, and human and social services agency records.

3. *Contact partner state and local government agencies who work with at-risk populations*: Reach out and collaborate with other public sector agencies who work directly with a variety of at-risk populations. For example, consider contacting departments of aging, social services, deaf and hard of hearing, maternal and child health, agriculture, law enforcement, and mental health.
4. *Reach out to community partners associated with at-risk populations*: For inclusive and whole community planning, reach out and partner with private and nonprofit community organizations and leaders working with and representing various at-risk populations. For example, faith-based organizations, immigration assistance agencies, homeless shelters, and primary (especially pediatric) healthcare providers all work with often overlooked groups of people.
5. *Plan and coordinate preparedness and response efforts in conjunction with all government and community partners*: Create a public health preparedness "system of systems" with robust and strategic partnerships and planning across public, private, and nonprofit sectors aimed at minimizing negative health outcomes of at-risk populations during all types of hazards.

Conclusion

Public health not only has responsibility to the population as a whole, but is frequently the safety net provider for at-risk populations. Many attributes contribute to the vulnerability of a community. Some are apparent and easily identifiable, but assumption of risk can result in overlooking vulnerabilities which are not so obvious. Using hazard assessments in the community allows for public health preparedness and resiliency planners to make actionable plans for those most vulnerable. Using a stepwise approach, whether risk- or hazard-based, will optimize plans for delivering valuable resources and services. Collaborative planning with individuals and agencies working day to day with at-risk and vulnerable individuals produces effective plans and leverages resources outside of traditional response agencies.

Websites

Agency for Toxic Substances and Disease Registry. Glossary of Terms. Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/glossary.html.

FEMA, Guidance on Planning for Integration of Functional Needs Support Services in General Population Shelters. http://www.fema.gov/pdf/about/odic/fnss_guidance.pdf.

National Response Framework, second ed. http://www.fema.gov/media-library-data/20130726-1914-25045-1246/final_national_response_framework_20130501.pdf.

U.S. Department of Justice, Information and Technical Assistance on American with Disabilities Act. http://www.ada.gov.

U.S. Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response. http://www.phe.gov.

U.S. Public Law No 109-417, 2006. Pandemic and All-hazards Preparedness Act (PAHPA) of 2006. http://www.gpo.gov/fdsys/pkg/PLAW-109publ417/pdf/PLAW-109publ417.pdf.

U.S. Public Law No 109-295, 2006. Post Katrina Emergency Management Reform Act of 2006. http://www.gpo.gov/fdsys/pkg/PLAW-109publ295/pdf/PLAW-109publ295.pdf.

U.S. Public Law No 110-325, 2008. American with Disabilities Act, 2008. http://www.ada.gov/pubs/adastatute08.pdf.

U.S. Public Law No 113-5, 2013. Pandemic and All-hazards Preparedness Reauthorization Act of 2013. http://www.gpo.gov/fdsys/pkg/PLAW-113publ5/html/PLAW-113publ5.htm.

U.S. Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response. At-risk Individuals. Public Health Emergency: Public Health and Medical Emergency Support for a Nation Prepared. http://www.phe.gov/Preparedness/planning/abc/Pages/at-risk.aspx.

References

Bea, K., Halchin, E., Hogue, H., Kaiser, F., Love, N., Reese, S., Schwemle, B., 2006. Federal Emergency Management Policy Changes after Hurricane Katrina: A Summary of Statutory Provisions. Congressional Research Services National Library of Congress. https://training.fema.gov/hiedu/docs/federal%20em%20policy%20changes%20after%20katrina.pdf.

Behr, J.G., Diaz, R., 2013. Disparate health implications stemming from the propensity of elderly and medically fragile populations to shelter in place during severe storm events. J. Public Health Manag. Pract. 2013 (19), S55–S62.

Cauchon, D., 2001. For Many on Sept. 11, Survival Was No Accident. USA Today. December 20, 2001. Available at: http://usatoday30.usatoday.com/news/sept11/2001/12/19/usatcov-wtcsurvival.htm.

Cutter, S.L., Boruff, B.J., Shirley, W.L., 2003. Social vulnerability to environmental hazards. Soc. Sci. Q. 84 (2), 242–261.

Flanagan, B.E., Gregory, E.W., Hallisey, E.J., Heitgerd, J.L., Lewis, B., 2011. A social vulnerability Index for disaster management. J. Homel. Secur. Emerg. Manag. 8 (1). http://dx.doi.org/10.2202/1547-7355.1792. Article 3 http://www.bepress.com/jhsem/vol8/iss1/3.

Hunter, M.D., Hunter, J.C., Yang, J.E., et al., 2015. Public health system response to extreme weather events [published online ahead of print January 9 2015]. J. Public Health Manag. Pract. http://dx.doi.org/10.1097/PHH.0000000000000204.

Jurgle, J., 2010. Vulnerable Populations, Planning for Their Needs before, during and after a Disaster. National Fire Academy, Emmitsburg, MD.

MacDonald, P.D.M., Horney, J.A., Bevc, C.A., Marciewicz, M., Gunther-Mohr, C., Simon, M.C., 2012. Vulnerable & At-risk Populations Resource Guide Introducing a New Tool for Preparedness Planning. Available at: https://sph.unc.edu/files/2015/07/nciph-perrc-varp-guide.pdf.

McMichael, A.J., Haines, A., Slooff, R., Kovats, S., et al., 1996. Climate change and human health: an assessment prepared by a task group on behalf of the world health organization, the world meteorological organization and the United Nations Environment Programme. In: Extreme Weather Events. World Health Organization, Geneva, Switzerland, pp. 123–144.

Van Kerkhove, M.D., Vandemaele, K.A.H., Shinde, V., Jaramillo-Gutierrez, G., Koukounari, A., et al., 2011. Risk factors for severe outcomes following 2009 Influenza a (H1N1) infection: a global pooled analysis. PLoS Med. 8 (7), e1001053. http://dx.doi.org/10.1371/journal.pmed.1001053.

Van Zandt, S., Peacock, W.G., Henry, D.W., Grover, H., Highfield, W.E., Brody, S.D., 2011. Mapping social vulnerability to enhance housing and neighborhood resilience. House Policy Debate 22 (1), 29–55.

5

Disaster Behavioral Health

OBJECTIVES

- List the most common psychological conditions resulting from disasters.
- Explain the prevalence and persistence of posttraumatic stress disorder (PTSD) following disasters.
- Define major depression disorder (MDD).
- List the symptoms of generalized anxiety disorder (GAD).
- Describe the organizations which typically deliver initial mental health support.
- List the seven components of critical incident stress management (CISM).
- Explain the criticisms of CISM.
- Define psychological first aid (PFA).
- List the eight core PFA actions.
- Describe faith-based crisis interventions.

Introduction: 2005 Post Hurricane Katrina Responder Suicide

Five days had passed since Hurricane Katrina made landfall near New Orleans, Louisiana (see Fig. 5-1). With the major levee breaches resulting from heavy rain and storm surge, over 80% of the city was flooded and the entire region had descended into turmoil. Many of the most vulnerable city residents remained trapped. Thousands sought shelter in the Superdome while many more could not escape their homes. Some sat on rooftops as they awaited rescue. Lawlessness overran many areas of the city as local law enforcement officials and other first responders attempted to restore order. Gunshots steadily echoed through the abandoned buildings of downtown as bodies floated by once vibrant areas of New Orleans. Looters used anything they could find, including air mattresses and trash cans, to float away with food, clothing, electronics, and other spoils of their pillaging. Even trucks bringing much-needed aid were being robbed at gunpoint as armed gangs openly carried out crimes across the city. Vigilante groups rose up in response and further escalated the violence (Leeaug, 2010; Nossiter, 2005).

Amidst the mayhem, Sergeant Paul James watched as his hometown descended into indescribable horror. As a public information officer with the New Orleans Police

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FIGURE 5-1 New Orleans, LA, Tuesday, August 30, 2005—Cars parked on the New Orleans streets are flooded to the top of the wheel wells in this ground level photograph. *Photo by Marty Bahamonde courtesy of the Federal Emergency Management Agency.*

Department, Paul had faced his share of tragedy. In his role, he was trained to deliver bad news and explain tragic events. He had done it at press conferences many times, with television cameras rolling and reporters asking hard questions.

His colleagues sometimes teased him about his tendency toward perfectionism. His uniform was always well pressed and perfect. His desk was so meticulously organized that his friends would sometimes play pranks by moving things around. After Hurricane Katrina, Paul's organized world was turned upside down. He lost his home in the flood waters, along with everything he owned, and was working long hours wading through throngs of desperate people at the Superdome and seeing deceased residents floating in the waters downtown. He grew more frustrated by the hour, trying to help people but with no resources to enable that support (O'Brien, 2005). Paul also wanted desperately to stop and help each lost animal he passed. His fellow officers noticed that he looked awful. It was clear that he was not sleeping and was experiencing depression. They encouraged him to "shake it off," but he could not. Paul was not alone in this dilemma. Everyone he worked with was experiencing stress unlike anything they had ever faced before. Sgt. Paul James faded into the crowd of frenzied, stressed first responders who were desperately trying to restore peace to their city.

After several days of this nightmarish situation, Paul pulled his car into a downtown New Orleans garage and began writing a note. The instructions simply asked whoever found him to notify a fellow police officer. He died that day of a self-inflicted gunshot wound (Burdeau, 2005). Fig. 5-2 is a photograph of Sergeant James.

FIGURE 5-2 Sergeant Paul James. *Image courtesy of the New Orleans Police Department.*

Disaster Behavioral Health Definitions

Agoraphobia A panic disorder resulting in extreme anxiety and avoidance of places or circumstances where escape is perceived to be difficult or help is not available. Circumstances commonly include crowded places and standing in lines.

Anxiety disorders Chronic, overwhelming fear and anxiety without a clear trigger or source. It is often accompanied by dizziness, nausea, sweating, and cardiac issues. Anxiety disorders include posttraumatic stress disorder (PTSD), panic disorder, agoraphobia, obsessive-compulsive disorder, and generalized anxiety disorders.

Bipolar disorder A mental illness also referred to as manic-depressive illness. It causes swings in a person's mood from euphoria to depression, impacting the person's energy level and ability to function.

Case management The process by which mental health services and care for each individual are managed over the course of illness and recovery. It connects patients with the appropriate support within their community.

Continuum of care The comprehensive range of mental health programs and services for children and adolescents. It includes services such as office visits, home care visits, day treatment, residential facilities, and hospitals.

Critical incident stress management (CISM) A short-term crisis intervention method with multiple components instituted across the lifecycle of a disaster.

Cultural competence An established aptitude, attitude, and skill set facilitating effective coordination with diverse religious, ethnic, or racial groups or individuals.

Dementia An illness resulting in deteriorating mental abilities, especially memory. Those with dementia may experience difficulties with self-care and communication. They also may become confused, hostile, or depressed.

Depression An illness ranging from mild to severe, often resulting in sadness, inactivity, and difficulty concentrating. Symptoms may include significant feelings of hopelessness, changes in appetite, and time spent sleeping. It may also be accompanied by thoughts of suicide. In recent years, it has become a very treatable illness.

Disaster behavioral health The provision of incident specific mental health outreach and crisis counseling services to those who have experienced, observed, or responded to disasters.

Early intervention Diagnosis and treatment of mental illness in the early stages of development. Early intervention results in higher recovery rates.

Generalized anxiety disorder (GAD) A condition characterized by extreme, irrepressible worry about everyday situations. It is not triggered by anything specific, making it distinct from phobias, and sometimes includes symptoms such as insomnia, dizziness, muscle aches, and gastrointestinal upset.

Major depression disorder (MDD) A common mood disorder related to ordinary emotions like sadness but persisting even when there is no reasonable cause. It is also disproportionate to an individual's circumstances.

Mental disorder A health condition mediated by the brain and characterized by alterations in thinking, mood, and/or behavior. These disorders can result from any combination of genetic, biological, environmental, or behavioral factors.

Mental health A state of well-being where individuals are able to cope effectively with normal stress. It is characterized by the absence of mental disorders and by sufficient adjustment to changing circumstances.

Mental illness Any diagnosable mental disorder.

Obsessive-compulsive disorder A mental disorder resulting in persistent, repetitive obsessions or thoughts of exaggerated anxiety and fear. It is frequently characterized by obsessive performance of routines or rituals.

Panic disorder A mental disorder resulting in sudden, unanticipated feelings of intense anxiety. Symptoms can include sweating, trembling, chest pain, heart palpitations, and extreme fear.

Personality disorders A mental disorder displaying a recurring pattern of atypical behavior.

Phobia Intense and sometimes incapacitating fear reaction to a situation or object which poses little or no actual threat.

Posttraumatic stress disorder (PTSD) A mental disorder triggered by experience or observation of a traumatic event. It is characterized by excessive anxiety, depression, nightmares, and irrepressible thoughts about the event. Events resulting in PTSD typically include combat experience, major disasters, or physical violence or abuse.

Psychiatry A branch of medicine dealing with the science and practice of treating mental, emotional or behavioral disorders.

Psychological first aid (PFA) A crisis intervention method used to reduce the initial psychological trauma of disasters. It is an evidence-informed approach built on the concept of human resilience and it extends beyond psychological to include social support.

Psychosis A severe mental disorder characterized by distorted or lost contact with reality; sometimes includes hallucinations or delusions resulting in abnormal social function.

Recovery A process by which those with mental illness are able to fully function in the community and live a fulfilling and productive life despite a disability; denotes the lessening or complete remission of symptoms.

Resilience An ability to recover from or adjust to major challenges associated with tragedy or change.

Schizophrenia A psychotic disorder characterized by deterioration of everyday mental function, degeneration of feelings, thoughts, and behavior, and disconnectedness from the environment; may include hallucinations and delusions.

Screening A brief formal or informal individual assessment to identify persons experiencing mental health problems or those likely to develop problems.

Therapy Treatment intended to cure or rehabilitate.

Disasters and Mental Health

Public health preparedness and response span the full range of human health disciplines. Provision of emergency medical care is perhaps the most visible postdisaster activity.

Public health activities to assure postdisaster community health are also apparent. However, disaster behavioral health response and recovery are among the most challenging, least apparent, and most overlooked aspects of any disaster response. The chapters of this book addressing specific threats describe unique challenges associated with each threat or disaster. A common denominator of all disasters is the impact on mental health (HHS, 2012). Therefore, the information in this chapter cuts across every threat described.

An important first step in any disaster preparedness or response activity is defining and understanding who is at risk. For example, during an influenza pandemic, those at increased risk of illness include those most physically vulnerable. The more susceptible populations typically include the elderly, the very young, or those with compromised immune function. In addition, for many natural disasters, risk is determined by proximity. Those closest to the threat are at greatest risk for hazardous exposures and physical injuries. Although the mental health impact of disasters is similarly influenced by proximity and preexisting conditions, populations at risk for the mental health impact of disasters cannot be as neatly ordered by demographics, proximity, or other factors. Anyone can experience psychological trauma during any phase of a disaster. Stress reactions to disasters are "normal responses of normal people to abnormal situations" and can be mitigated and managed with the correct planning and response. In a similar statement, World War II concentration camp survivor Viktor Frankl once said, "An abnormal reaction to an abnormal situation is normal behavior" (Scurfield, 2002). The point shared by both statements is that it's normal for an individual to experience a range of varying degrees of psychological symptoms as a reaction to traumatic events. Unfortunately, the social stigma associated with mental illness occasionally still surfaces in some communities and professions. More education is needed in order to overcome historical misconceptions.

Mental Health Effects of Disasters

The study of psychology dates back to the early Greeks, including Plato, Aristotle, and Socrates. The word psychology is derived from the Greek word "psyche," which is broadly defined as the human mind. While the roots of modern psychology are found in philosophy, the evolution of psychiatry and the study of the human brain's biological functions have led to remarkable advances in mental health. The modern study of psychology has both academic and applied pathways. Academic pursuits strive to understand people's emotions and behaviors, while applied psychology is the use of that information to overcome mental health problems. The field of disaster behavioral health (DBH) is a relatively new area of study and practice. Although much has been learned over the past several decades, there are still many gaps in understanding DBH and effectively intervening to reduce the mental health impact resulting from disasters.

A variety of possible psychological symptoms or disorders can result from disasters. These conditions stem from the exposures and experiences of those directly impacted. Individuals may experience very real threats to their lives and safety or witness death or the occurrence of serious injuries. Some may also experience great personal loss of family, friends, and property. The most common psychological conditions resulting include PTSD, MDD, and GAD.

Table 5-1 PTSD Prevalence by Trauma Type

Trauma	PTSD Prevalence
Rape	80%
Crime victims	19–75%
Direct disaster victims	30–40%
Rescue workers	10–20%
First responders	6–32%
General population	4%

(Javidi and Yadollahie, 2012)

Posttraumatic Stress Disorder

PTSD is an anxiety disorder resulting from exposure to traumatic events. It is not a new condition. PTSD was recognized in the early 1900s among soldiers and called "battle fatigue" or "shell shock". The symptoms fall into four general categories including intrusion, avoidance, hyperarousal, and negative thoughts and mood (APA, 2013). Intrusion is the incapability of preventing recurring traumatic memories. Memories may include sights, smells, feelings, and thoughts associated with the traumatic event, and feeling like the event is occurring again. Avoidance is the attempt to evade stimuli and triggers for bad memories. It includes avoiding people, places, or activities suggestive of the event, and can also extend to avoidance of any strong personal feelings and emotions. Hyperarousal may include difficulty concentrating, trouble sleeping, irritability, and jumpiness or a tendency to be easily startled (NATAL, 2015). PTSD is also associated with depression. PTSD can be either acute or chronic, with acute PTSD persisting for three months or less and chronic PTSD lasting longer than three months. This condition is experienced by about 4% of the global population, with differences among nations and types of traumatic exposures (Javidi and Yadollahie, 2012). Table 5-1 shows the prevalence of PTSD for some specific trauma types. It also may contribute to MDD and GAD.

The Buffalo Creek Flood disaster occurred on February 26, 1972. A dam comprising coal waste from mining operations was built to contain wastewater and refuse just above a flood plain, with over a dozen small towns below. The dam had failed twice before in previous years while holding a relatively small amount of wastewater. Both times it was poorly repaired. After several years of waste accumulation and seasonal rain, the dam was holding over 132 million gallons (500 million L) of runoff and wastewater. A catastrophic dam failure occurred, cutting a 17-mile (27 km) path of destruction, killing 125, injuring 1100, and leaving 4000 homeless (WVDCH, 2015). A prospective PTSD prevalence study was accomplished at 2 years and 14 years following the Buffalo Creek disaster. The study found that 2 years after the event, 44% of disaster survivors were experiencing PTSD. At 14 years postdisaster, prevalence had dropped to 28% (Grace et al., 1993).

The Oklahoma City Bombing occurred April 19, 1995. A truck bomb parked in front of the Alfred P. Murrah Federal Building in downtown Oklahoma City collapsed the front of the building, claiming 168 lives including 19 children, and injuring hundreds. It was the first major terrorist attack on US soil, and was perpetrated by antigovernment domestic terrorists. A prospective study of 113 bombing survivors found that 41% experienced PTSD 6 months after the event. Seven years later, the prevalence had dropped to 26% (North et al., 2011). Disaster victim PTSD prevalence decreases over time.

Buffalo Creek Flood, 1972	**Oklahoma City Bombing, 1995**
44% PTSD prevalence at 2 years	41% PTSD prevalence at 6 months
28% PTSD prevalence at 14 years	26% PTSD prevalence at 7 years

Major Depression Disorder

MDD is a common mood disorder. Although it is related to ordinary emotions such as sadness, it persists even when there is no reasonable cause and is also disproportionate to an individual's circumstances. It is recognized through distinct changes in mood, with persistent sadness and detachment. MDD not only changes the way a person feels, it also changes thoughts, behaviors, and physiology. Eventually it can result in serious emotional and physical health problems. The lifetime US incidence of depression in the general population is more than 12% in men and 20% in women (Belmaker and Agam, 2008). It is also the second most common mental health issue among disaster victims. MDD prevalence increases following disasters and is observed in about 36% of those directly impacted (Norris et al., 2002).

Generalized Anxiety Disorder

GAD is a psychological condition characterized by excessive, uncontrollable worry and anxiety, occurring more than half the time for at least 6 months. (Andrews et al., 2010) It is accompanied by three or more of the following:

- restlessness or edginess
- being easily fatigued
- difficulty concentrating or mind going blank
- irritability
- muscle tension
- sleep disturbance

Those experiencing GAD are often aware that their level of anxiety is not commensurate with their circumstances, but cannot control it. It occurs in about 20% of disaster victims (Norris et al., 2002).

Disaster Behavioral Health Preparedness, Response, and Recovery

Disaster behavioral health (DBH) preparedness begins with community, family, and individual resilience (See chapter Community Disaster Resilience). A community with greater social cohesion will respond more effectively and recover more rapidly. The connectedness of community members and their ability to work together will support sustainment of critical systems, adaptation to change, and improved self-reliance (Arbon et al., 2012). Families and individuals who have taken basic preparedness measures can mitigate some of the initial stressors. Having a feeling of control over the details may help psychological coping and recovery. Maintaining an emergency supply kit with food, water, flashlight, radio, and other basic necessities mitigates the initial shock and potential feelings of helplessness. Possessing passports or other personal identification, insurance documents, and similar important documents reduces the burden of initiating the recovery process. Ensuring that basic plans for evacuation and communication have been established and shared with key friends or family members diminishes the anxiety of not knowing where to go or how to ensure reunification when separated. Following the instructions of local officials can reduce risks to personal safety and improve access to emergency resources.

DBH response planning and response must extend beyond mental health professionals and their normal activities. The need for services and case management can quickly rise and exceed local resources. In a widespread disaster, local mental health service providers will sometimes be victims as well, further reducing available services and support. DBH professionals are heavily reliant upon an assortment of response organizations and volunteers to deliver initial mental health support to disaster victims. This includes embedding DBH-trained fire, police, EMS, public health, and hospital responders; using faith-based and other nongovernmental response organizations for support; and in the United States, using Medical Reserve Corps and Community Emergency Response Team volunteers. However, in order for any individual or group to effectively provide DBH field support, they must have the appropriate training and not exceed the functional limits of their role, training, and capabilities. A robust number of DBH-trained personnel is essential for an effective mental health response to a widespread disaster with a large number of victims and witnesses. Individuals in need of DBH support do not typically seek assistance. They are identified through interactions with trained responders and volunteers across the impacted community during response and cleanup, in shelters, at community meetings, etc.

Depending upon the target recipients of DBH support, training may include but is not limited to CISM, PFA, faith-based interventions, or a combination of the three. There has been a debate among researchers on the efficacy of each approach. Both CISM and PFA are intended to reduce psychological trauma such as PTSD, but there are fundamental differences between the two methods. CISM uses debriefing and discussion approaches. PFA takes less of a counseling approach, focusing more broadly on meeting the immediate needs of the trauma victim.

New York, NY, September 27, 2001—Members of Colorado Task Force-1 receive instructions before entering Ground Zero at the World Trade Center. *Photo by Michael Rieger courtesy of the Federal Emergency Management Agency.*

Critical Incident Stress Management

CISM is intended to mitigate PTSD and other psychological sequela resulting from trauma. It is used for individuals as well as groups of all sizes. It is sometimes confused as being a single-session debriefing intervention and has been criticized as such (Mitchell, 2003). However, CISM comprises multiple components. A number of variations to these components have been instituted by various organizations around the world. The International Critical Incident Stress Foundation promotes seven components which may be instituted across the lifecycle of a disaster:

1. precrisis preparation: stress management education, stress resistance, and crisis mitigation training for individuals and organizations
2. disaster or large-scale incident and school and community support programs including demobilizations, informational briefings, "town meetings," and staff advisement
3. defusing: a three-phase structured small group discussion provided within hours of a crisis for purposes of assessment, triaging, and acute symptom mitigation
4. critical incident stress debriefing: a seven-phase structured group discussion usually provided 1 to 10 days postcrisis and designed to mitigate acute symptoms, assess the need for follow-up, and if possible provide a sense of postcrisis psychological closure

5. one-on-one crisis intervention/counseling or psychological support throughout the full range of the crisis spectrum
6. family crisis intervention as well as organizational consultation
7. follow-up and referral mechanisms for assessment and treatment, if necessary
Everly and Mitchell (2011).

CISM support must be provided by trained and certified individuals. Peer debriefers are usually not mental health professionals, but coworkers within various agencies trained to work with their colleagues. Peer counselors are much more acceptable in many professions, including police and fire agencies, where trust is based on an understanding of shared experience. Anecdotally, CISM has been very successful for thousands of disaster victims and first responders. However, most studies on the efficacy of CISM agree that more research is needed. After decades of study, many researchers believe that results remain inconclusive (Tuckey, 2007; Jeannette and Scoboria, 2008).

Psychological First Aid

PFA is another crisis intervention method used to reduce the initial psychological trauma of disasters. It extends beyond psychological to include social support. PFA is promoted by the World Health Organization, Inter-Agency Standing Committee, and the SPHERE Project (IASC, 2007; Sphere Project, 2011). These groups are responsible for setting international standards for humanitarian relief, and describe PFA as a "humane, supportive response to a fellow human being who is suffering and who may need support." It includes the following fundamental themes:

- providing practical care and support which does not intrude
- assessing needs and concerns
- helping people to address basic needs (for example, food, water, and information)
- listening to people, but not pressuring them to talk
- comforting people and helping them to feel calm
- helping people connect to information, services, and social support
- protecting people from further harm
WHO (2011).

What PFA is not is equally important. It is not a process used exclusively by professional counselors. The principles and processes can be used successfully by anyone with even minimal training. It is also not a "debriefing." The debriefing approach used by those trained in CISM can be beneficial to the right groups under the right circumstances when led by someone with the right training and experience, but PFA does not "debrief." It is also not a psychological analysis of a disaster victim. It involves more listening than inquiry, and should never pressure anyone to share detailed events and feelings. PFA is not intended for those who have life-threatening injuries needing emergency medical care, are too upset to take care of themselves or those who are dependent upon them, or may hurt themselves or others.

According to the *Psychological First Aid: Field Operations Guide* developed by the National Child Traumatic Stress Network and National Center for PTSD, there are eight core PFA actions used in the days and weeks following a disaster. The order and emphasis of these actions should be adjusted according to the unique circumstances and needs of each disaster victim and include the following:

1. contact and engagement: responding appropriately to disaster victims reaching out for assistance, and reaching out in a useful, supportive, and nonintrusive manner
2. safety and comfort: ensuring immediate safety and providing physical and emotional support
3. stabilization: calming and reassuring those who are overwhelmed and disorientated
4. information gathering: identifying immediate needs and anxieties in order to tailor the most supportive response
5. practical assistance: offering practical support for immediate needs
6. connection with social support: helping reconnect the disaster victim with family, friends, and community assistance resources
7. information on coping: sharing information on stress reactions and sharing simple coping strategies
8. linkage with collaboration: linking disaster victims with resources and services to support physical and emotional recovery
   NCTSN and NCPTSD (2006).

Disaster Behavioral Health in Israel

PFA is used by many nations, including Israel. Israelis have experienced many attacks and have dealt with many more psychological than physical injuries. Their first line of mental health defense is individual PFA. It begins with reassuring supportive words and compassionate touch as appropriate. The survivors are reoriented about what has happened and what will happen next while being encouraged to verbalize their personal experiences. Efforts are made to place them in contact with family or friends as their immediate physical needs are met including water, food, and a peaceful setting.

The first responders usually engage in a group encounter similar to CISM within 3 hours of the response. The group of 5–12 responders is led by two mental health professionals in a session lasting about 45 minutes. Participants recognized as being at increased risk of PTSD or other disorders are provided with additional guidance and referrals. The responder group intervention has five objectives:

1. Reduce any sense of isolation and recognize a "shared fate."
2. Provide human contact and mutual support to foster security and independence.
3. Develop a narrative which places the experience into words.
4. Repeat the exposure through retelling the event without reexperiencing it.
5. Express and share emotions with the group (heart storming).
   Kutz and Bleich (2005).

Faith-Based Counseling and Support

During times of major traumas and disasters, a large segment the world's population often turns to their faith. In spite of this obvious proclivity, there is often a conspicuous absence of faith-based resources as part of "formalized" preparedness and response activities. Faith-based crisis intervention adds impactful tools that can encourage survivors of various faiths in ways traditional disaster behavioral health strategies cannot (see Fig. 5-3). For many faiths, this includes but is not limited to:

- individual and group prayer bringing peace of mind
- the notion of divine protection bringing security
- assurance of life after death providing comfort
- rituals and sacraments restoring stability and normalcy
- the notion of divine forgiveness and compassion bringing reconciliation
- expressions of confession relieving guilt
- education and insights of religious writings providing disaster context
- tenets of service and giving to others taking focus off personal distress
- unifying spiritual world views bringing perspective and order to disasters
- a faith-based social support system providing spiritual, emotional, and physical support

Adapted from Everly and Lating (2013) and Everly (2000).

FIGURE 5-3 Moore, OK, June 12, 2013—A chaplain with Southern Baptist Disaster Relief prays with a local resident at the site of the Plaza Towers Elementary School memorial. *Photo by Jocelyn Augustino courtesy of the Federal Emergency Management Agency.*

Summary

Psychological crisis occurs when usual coping mechanisms fail and can lead to conditions including PTSD, MDD, and GAD. The symptoms of these disorders can manifest

themselves as an individual reacts to an abnormal event imposed by disasters. Those exposed directly to a mass disaster are the most likely to develop one or more of these disorders. In fact, as many as 45% of individuals directly exposed to a mass disaster may develop PTSD or MDD (North et al., 1999). Postdisaster indicators of this impact include the demand for mental health and substance abuse services, and increasing calls to hotlines for domestic abuse and suicide prevention (Galea et al., 2007). Additional indicators can be seen in crime statistics, with increased rates of theft, assault, and driving while intoxicated following a disaster (Yun et al., 2010).

The ability of a community to rebound and rebuild after a disaster depends upon the mental health condition of residents. Few people seek out needed psychological support and expertise following disasters, but strategies have been developed to provide initial postdisaster support. These strategies include CISM, PFA, and faith-based interventions. Delivery of most initial postdisaster mental health support is by non–mental health professionals. Individuals providing this essential support come from a variety of response and volunteer organizations. Successful provision of this support requires outreach by individuals with appropriate training and experience with any strategy they use.

The intervention strategies described in this chapter represent one point on the continuum of psychological care following a disaster. None of these strategies should take priority over first meeting the most basic needs of a disaster victim, including assuring that they are in a safe location, providing physical care including reducing pain, and providing water, food, and a means to communicate and initiate reunification with family or friends. Once these basic needs are met, the provision of disaster behavioral health support becomes equally important.

Websites

American Red Cross, Disaster Services, Disaster Mental Health Handbook. http://www.cdms.uci.edu/PDF/Disaster-Mental-Health-Handbook-Oct-2012.pdf.

Centers for Disease Control and Prevention, Coping with a Disaster or Traumatic Event. http://emergency.cdc.gov/mentalhealth/.

Institute of Medicine Preparedness, Response, and Recovery Considerations for Children and Families: Workshop Summary. http://www.ncbi.nlm.nih.gov/books/NBK195865/.

Inter-Agency Standing Committee (IASC), 2007. IASC Guidelines on Mental Health and Psychosocial Support in Emergency Settings. Geneva, IASC. http://www.who.int/mental_health/emergencies/9781424334445/en/.

Johns Hopkins Center for Public Health Preparedness, Disaster Mental Health Intervention On-line Training. http://www.jhsph.edu/research/centers-and-institutes/johns-hopkins-center-for-public-health-preparedness/training/online/mtl_hlth_intervention.html.

National Child Traumatic Stress Network (NCTSN) and National Center for PTSD (NCPTSD), Psychological First Aid: Field Operations Guide, July 2006, second ed. Available in English, Spanish, Japanese, and Chinese. http://www.nctsn.org/content/psychological-first-aid.

Sphere Project, 2011. Humanitarian Charter and Minimum Standards in Disaster Response. Geneva, The Sphere Project. http://www.sphereproject.org.

U.S. Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response, Behavioral Health. http://www.phe.gov/Preparedness/planning/abc/Pages/behavioral-health.aspx.

World Health Organization (WHO), 2011. Psychological First Aid: Guide for Field Workers. War Trauma Foundation and World Vision International. Available at: http://www.who.int/mental_health/publications/guide_field_workers/en/.

References

American Psychiatric Association (APA), 2013. Diagnostic and Statistical Manual of Mental Disorders, fifth ed. Author, Washington, DC.

Andrews, G., Hobbs, M.J., Borkovec, T.D., Beesdo, K., Craske, M.G., Heimberg, R.G., Rapee, R.M., Ruscio, A.M., Stanley, M.A., February 2010. Generalized worry disorder: a review of DSM-IV generalized anxiety disorder and options for DSM-V. Depress Anxiety 27 (2), 134–147. http://dx.doi.org/10.1002/da.20658.

Arbon, P., Gebbie, K., Cusack, L., Perera, S., Verdonk, S., 2012. Developing a Model and Tool to Measure Community Disaster Resilience: Final Report October 2012. TORRENS Resilience Institute. Retrieved September 3, 2014. http://static.placestories.com/pool/doc/38/31/11/667iz-16372d31e23973f8ed918a6c1c.pdf.

Belmaker, R.H., Agam, G., 2008. Major depressive disorder. N. Engl. J. Med. 358, 55–68.

Burdeau, C., 2005. Chaos of Katrina Drives Police Officer to Suicide. PoliceOne.com. September 6, 2005. Available at: http://www.policeone.com/health-fitness/articles/118576-Chaos-of-Katrina-drives-police-officer-to-suicide/.

Everly, G.S., 2000. Pastoral crisis intervention: toward a definition. Int. J. Emerg. Ment. Health 2 (2), 69–71 Spring.

Everly, G.S., Mitchell, J.T., 2011. A Primer on Critical Incident Stress Management (CISM). The International Critical Incident Stress Foundation. Available at: http://www.icisf.org/a-primer-on-critical-incident-stress-management-cism/.

Everly, G.S., Lating, J.M., 2013. A Clinical Guide to the Treatment of the Human Stress Response, third ed. Springer, New York.

Galea, S., Brewin, C.R., Gruber, M., et al., 2007. Exposure to hurricane-related stressors and mental illness after Hurricane Katrina. Arch. Gen. Psychiatry 64, 1427–1434.

Grace, M.C., Green, B.L., Lindy, J.L., Leonard, A.C., 1993. The Buffalo creek disaster: a 14-year follow-up. In: Wilson, J.P., Raphael, B. (Eds.), International Handbook of Traumatic Stress Syndromes. Plenum, New York, pp. 441–449.

Inter-Agency Standing Committee (IASC), 2007. IASC Guidelines on Mental Health and Psychosocial Support in Emergency Settings. Geneva: IASC. Available at: http://www.who.int/mental_health/emergencies/9781424334445/en/.

Javidi, H., Yadollahie, M., January 2012. Post-traumatic stress disorder. Int. J. Occup. Environ. Med. 3 (1), 2–9.

Jeannette, J., Scoboria, A., October–December 2008. Firefighter preferences regarding post-incident intervention. Work Stress 22 (4), 314–326.

Kutz, I., Bleich, A., 2005. Psychological first aid, acute and long-term treatment following terrorist attacks—mental health interventions in a general hospital following terrorist attacks: the Israeli experience. In: Danieli, Y., Brom, D., Sills, J. (Eds.), The Trauma of Terrorism. The Haworth Maltreatment & Trauma Press, Binghamton, pp. 425–437.

Leeaug, T., 2010. Rumor to Fact in Tales of Post-Katrina Violence. The New York Times. August 26, 2010. Available at: http://www.nytimes.com/2010/08/27/us/27racial.html?_r=0.

Mitchell, J.T., 2003. Crisis Intervention & CISM: A Research Summary. International Critical Incident Stress Foundation. Available at: http://www.icisf.org/wp-content/uploads/2013/04/Crisis-Intervention-and-CISM-A-Research-Summary.pdf.

NATAL, Israel Trauma Center for Victims of Terror and War, 2015. Post Traumatic Stress Disorder: What Is Post Trauma. Available at: http://www.natal.org.il/english/?CategoryID=227.

National Child Traumatic Stress Network (NCTSN) and National Center for PTSD (NCPTSD), July 2006. Psychological First Aid: Field Operations Guide, 2nd Edition. Available at: http://www.nctsn.org/content/psychological-first-aid.

Norris, F.H., Friedman, M.J., Watson, P.J., Byrne, C.M., Diaz, E., Kaniasty, K., 2002 Fall. 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981-2001. Psychiatry 65 (3), 207–239.

North, C.S., Nixon, S.J., Shariat, S., Mallonee, S., McMillen, J.C., Spitznagel, E.L., Smith, E.M., August 25, 1999. Psychiatric disorders among survivors of the Oklahoma City bombing. JAMA 282 (8), 755–762.

North, C.S., Pfefferbaum, B., Kawasaki, A., Lee, S., Spitznagel, E.L., January–February 2011. Psychosocial adjustment of directly exposed survivors 7 years after the Oklahoma City bombing. Compr. Psychiatry 52 (1), 1–8. http://dx.doi.org/10.1016/j.comppsych.2010.04.003 Epub 2010 June 26.

Nossiter, A., September 1, 2005. New Orleans police Abandon Rescue Efforts as Looting Escalates. The San Diego Union-Tribune. Available at: http://legacy.utsandiego.com/news/nation/20050901-0506-hurricanekatrina.html.

O'Brien, K., September 5, 2005. Amid Horror, 2 Officers Commit Suicide: "World Can't Understand". Boston Globe. Available at: http://www.boston.com/news/nation/articles/2005/09/05/amid_horror_2_officers_commit_suicide/.

Sphere Project, 2011. Humanitarian Charter and Minimum Standards in Disaster Response. Geneva: The Sphere Project. Available at: http://www.sphereproject.org.

Scurfield, R.M., January 1, 2002. The Normal Abnormal: Psychological Wounds Don't Heal Easily. But You Can Use These Coping Strategies to Help Process Post-9/11 Trauma. Psychology Today. Available at: https://www.psychologytoday.com/articles/200201/the-normal-abnormal.

Tuckey, M.R., 2007. Issues in the Debriefing Debate for the Emergency Services: Moving Research Outcomes Forward. Work & Stress Research Group, Centre for Applied Psychology, University of South Australia, p. 106.

U.S. Department of Health and Human Services (HHS), 2012. Office of the Assistant Secretary for Preparedness and Response, Disaster Behavioral Health Fact Sheet. Available at: http://www.phe.gov/Preparedness/planning/abc/Pages/disaster-behavioral.aspx.

West Virginia Division of Culture and History (WVDCH), February 26, 2015. Buffalo Creek Dam Disaster. Available at: http://www.wvculture.org/history/buffcreek/buff1.html.

World Health Organization (WHO), 2011. Psychological First Aid: Guide for Field Workers. War Trauma Foundation and World Vision International. Available at: http://www.who.int/mental_health/publications/guide_field_workers/en/.

Yun, K., Lurie, N., Hyde, P.S., September 23, 2010. Moving mental health into the disaster-preparedness spotlight. N. Engl. J. Med. 363, 1193–1195. http://dx.doi.org/10.1056/NEJMp1008304.

6

Bioterrorism

OBJECTIVES

- Differentiate bioterrorism from emerging infectious disease outbreaks.
- Discuss the controversies surrounding bioterrorism preparedness.
- List the highest-priority, highest-risk biological agents.
- List the epidemiological clues indicating a possible bioterrorism attack.
- Describe the common characteristics of Category A biological agents.
- Explain the criteria used to classify bioterrorism agent threats.
- Identify diagnosis and treatment recommendations for critical agents.
- Describe various types of bioterrorism surveillance approaches.
- Explain how environmental surveillance is used to identify the presence of suspicious organisms.
- Recognize the infection control precautions needed for responding to bioterrorism.

Introduction: US Bioterrorism Incident: 2001 Anthrax Letters

They were two men going about their daily lives. Both had reputations as pillars of the community in the Washington, DC, area. Joseph Curseen Jr. (Fig. 6-1) was 47 years old and had followed in his father's footsteps. He enjoyed his job with the US Postal Service and had not used a day of sick leave in 15 years (Becker and Toner, 2001). His coworker and friend, Thomas Morris Jr. (Fig. 6-2), was 55 years old. Mr. Morris was the first to experience mysterious symptoms after suspicious letters with anthrax threats were processed at the Brentwood postal facility where both men worked. After several days of a "flu-like" illness and a trip to his doctor's office, Mr. Morris had been told by his physician his illness was likely due to a virus. On October 21, 2001, he placed a 911 phone call when his health took a turn for the worst. He had begun vomiting while at work and called for help. He told the 911 operator he thought he might have been exposed to anthrax. Unfortunately, it was too late to intervene (CNN, 2001; Morris, 2001). Mr. Morris died that day and Mr. Curseen's death followed the next day. These were two of the five people who died following exposure to anthrax-laced letters sent to US senators and media outlets during the weeks following the terrorist attacks of September 11, 2001 (Figs. 6-3 and 6-4). Another 17 people were sickened by associated anthrax exposures. The Brentwood postal facility was decontaminated and reopened in 2003 under the name: The Joseph Curseen, Jr., and Thomas Morris, Jr., Processing and Distribution Center. A dedication plaque on the building says: "We are poorer for their loss but richer for having been touched by these dedicated, hard-working heroes. We will never forget."

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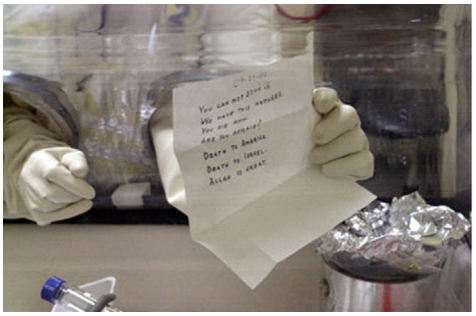
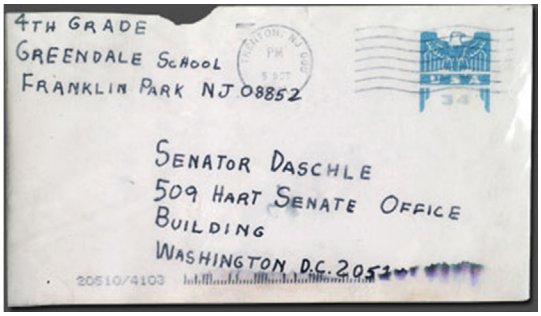
FIGURE 6-1 Joseph Curseen Jr. *Photographs courtesy of the US Postal Service.*

FIGURE 6-2 Thomas Morris Jr. *Photographs courtesy of the US Postal Service.*





FIGURES 6-3 and 6-4 One of the anthrax-tainted letters that passed through the Brentwood postal facility. *Photograph courtesy of the Federal Bureau of Investigation.*

The "anthrax letters" of 2001 set US public health preparedness initiatives in motion that continue today. Billions of dollars have been spent to develop new drugs and vaccines, place biothreat agent detection equipment in major cities and at important events, enhance laboratory capabilities, expand epidemiological monitoring, increase hospital decontamination and surge capacity, and accomplish planning, training, and exercises across a wide range of related professions. Details have emerged suggesting Dr. Bruce Ivins, an employee of the US Army Medical Research Institute of Infectious Diseases (USAMRIID) at Fort Detrick, Maryland, was responsible for the letters. Although there is strong circumstantial and forensic evidence pointing to Dr. Ivins, his suicide during the investigation will keep the details cloaked in mystery (Lichtblau and Wade, 2008).

Bioterrorism Definitions

Bacteremia Presence of bacteria in the blood. Fever, chills, tachycardia, and tachypnea are common manifestations of bacteremia.
Bubonic Relating to an inflamed, enlarged lymph gland.
Encephalitis Inflammation of the brain due to infection, toxins, and other conditions.
Fever Abnormal elevation of body temperature (>100°F/38°C), usually resulting from infection.
Hemorrhagic Related to bleeding or hemorrhage.
Hypotension Abnormally low blood pressure; seen in shock.
Maculopapular Rash of the skin consisting of both spots (macules) and elevations of the skin (papules).
Papular Characterized by the presence of small, circumscribed, solid elevations of the skin.
Petechiae Purplish or brownish red discoloration, visible through the epidermis, caused by bleeding into the tissues.
Pneumonic Related to an inflammation of the lungs.
Prodrome Early symptom of a disease.
Sepsis Presence of microorganisms or their toxins in tissues or in the blood. Systemic disease caused by the spread of the microorganisms or their byproducts via the circulating blood is commonly called septicemia.
Septicemic Related to a systemic disease associated with the presence of microorganisms or their toxic byproducts in the blood.
Septic shock Shock due to circulatory inadequacy caused by gram-negative bacteria (bacteremia). It is less often the result of the presence of other microorganisms (fungus or virus) in the blood resulting in fungemia or viremia, respectively.
Shock Imbalanced condition of the hemodynamic equilibrium, usually manifested by failure to oxygenate vital organs.

Basic Facts About Bioterrorism

Bioterrorism is the use or threatened use of biological agents as weapons of terror. Current US laws make the threat alone, even in the absence of dangerous biological material possession or use, a serious crime. Many other countries also have laws against the threatened use of biologicals as agents of terrorism Fidler, 2002. The international community agreed with the passage of the United Nations Convention on the Suppression of Terrorist Bombings, ironically in May 2001. Biological material used in an act of bioterrorism may be lethal or nonlethal, a common bacteria or virus, the toxic byproduct of a pathogen, a rare organism, or even a specially engineered organism, never before diagnosed or treated. Although most public concerns focus on the threat to humans, bioterrorists may also attack crops or livestock. Even a small attack on these resources can result in serious economic consequences for any nation targeted. Regardless of the focus of an attack or the agent used, the ultimate goal of bioterrorism is the same as conventional terrorism. These acts are intended to instill fear in the targeted population in support of terrorists' social or political goals.

Bioterrorism continues to be one of the most complex public health preparedness challenges. Importantly, there are distinctions from the other disasters described in this book. Most disasters have a focal point. Resources are clearly needed in a relatively well-defined

area following an earthquake, hurricane, or other natural disaster. The hazardous chemical exposures of greatest concern are typically acute and those affected are quickly seen among those exposed. Naturally occurring diseases often have a relatively slow moving progression as an epidemic unfolds over weeks or months. Conversely, bioterrorism can cause a large, delayed surge of severely ill people spread out across multiple communities or even multiple continents. Organisms or other biological materials can be released in the air, or placed in food or water sources. With incubation periods of days or weeks for many agents, it is difficult to find all the individuals who may have been exposed to an intentional release and to successfully treat them in order to avert full blown disease. In a naturally occurring event, it is easier for any people to assign causality to their deity or to nature but in a terrorist event, the collective population wants to find blame and retaliate. There may be heightened fear not only from the attack itself but from heightened security and changes in "normal" life. This psychological need may alter response and recovery activities for the community. As a result, it is likely the response will include an enormous number of potentially exposed and affected individuals in multiple regions. Unlike many other disasters, a window of opportunity exists for a bioterrorism response. Most conditions can be successfully averted if caught early and prophylactically treated. As treatment is delayed, morbidity and mortality increase daily as the end of the incubation period is reached. The challenge of responding increases with some high-threat organisms spread from person-to-person. These organisms can also be engineered to optimize release effectiveness or even to make them impossible to treat with standard therapies. A unique aspect of the public health and healthcare response to these scenarios is that their organizations are placed in the vanguard of a response. In most other disaster scenarios, the public health and healthcare roles are in support of emergency management and first responders. In the case of bioterrorism, the majority of response will be identifying and treating those at risk.

There is a long history associated with biological weapons (Table 6-1). Thousands of years ago, before any understanding of pathogenic organisms, there was an initial observation that various biological materials could cause illness. A variety of plants were known to be poisonous, but in addition there was a growing understanding that feces, blood, tissue from dead bodies, or entire dead bodies of sick humans or animals, were able to cause illness and could be used as weapons. This crude use of filth and carcasses was the beginning of biological warfare and bioterrorism. The twentieth century saw a rapid acceleration in life sciences and a growing group of scientific professionals, including microbiologists, physicians, and many other disciplines working covertly on the development of biological weapons. Although most nations acknowledge these weapons should be banned and signed the Biological Weapons Convention in 1972 stating they would no longer pursue them for offensive purposes, some nation-sponsored programs continued to develop bio-weapons. The same advances used to combat disease and advance health, namely pharmaceutical development, genetic manipulation of organisms, and understanding how disease affect the body's immune system, can be used to develop more powerful and unique weapons. However, there appears to be

Table 6-1 Select Historical Events Involving Biological Weapons and Bioterrorism

c.<1000 BC	Scythian archers tipped arrows with blood, manure, and tissue from dead bodies.
c.5 BC	Assyrians poisoned enemy wells with rye ergot (*Claviceps purpurea*), a fungus containing mycotoxins.
590 BC	Athenians poisoned enemy water supplies with hellebore, an herb purgative, during the Siege of Krissa.
c.3 BC	Persian, Greek, and Roman literature describes the use of dead animals being used to contaminate enemy water supplies.
184 BC	Carthaginian general Hannibal ordered his sailors to hurl clay pots filled with poisonous snakes onto the decks of enemy ships during a naval battle. Hannibal won the battle.
1155	Emperor Barbarossa poisons wells with decomposing human bodies.
1346	Tartur army catapulted deceased bodies of plague victims over city walls during the siege of Caffa.
1495	Spanish sell wine mixed with the blood of lepers to their enemies.
1763	British distribute variola virus contaminated blankets to Native Americans resulting in a smallpox outbreak.
1797	Napoleon floods fields around Mantua to promote malaria.
1915–18	Germans attempt to infect Allied horses with anthrax and glanders.
1932–45	Japanese operate Unit 731 in Manchuria conducting experiments that included infecting prisoners with a variety of lethal pathogens.
1942	British test anthrax bombs on Gruinard Island off the coast of Scotland.
1950–69	US and USSR grow offensive biological weapons programs.
1969	US President Nixon ends the US offensive biological weapons program.
1972	US and USSR sign the biological weapons convention agreeing to an end to offensive programs.
1978	Assassination of Bulgarian exile Georgi Markov in London with an injected ricin pellet.
1979	Accidental anthrax release from a secret Soviet facility in Sverdlovsk kills 66.
1984	In the Dalles, Oregon, USA, the Rajneeshee cult contaminated local salad bars with *Salmonella* sickening more than 750 people.
1990	Japanese Aum Shinrikyo cult unsuccessfully attempts botulinum toxin releases in Tokyo.
1991	US troops receive anthrax vaccinations.
1991	After the first Gulf war, UN inspectors begin inspections of biological weapons capability in Iraq. Iraqi government officials confirm they had researched the use of anthrax and botulism.
1993	Aum Shinrikyo cult unsuccessfully attempts a second botulinum toxin attack on the wedding of the Crown Prince. Later the same month they unsuccessfully attempted to release anthrax from a Tokyo high rise.
2001	Anthrax contaminated letters mailed to US Senate offices and media outlets sickening 22 and killing five.
2004	Ricin sent to US Senate majority leader bill Frist's office.
2009	The managers of 11 gay bars in the Capitol Hill region of Seattle, Washington, USA received letters from an anonymous sender claiming to be in possession of 67 g of ricin that would be used to dose exactly five patrons from each establishment with the intent of killing them.
2011	In 2014, two men from Gainesville, Georgia, US, were each sentenced 10 years in prison for a 2011 antigovernment plot to disperse ricin in five American cities.
2013	In 2014, a woman from New Boston, Texas, US, was sentenced to 18 years in prison for a May 2013 incident. She mailed letters containing ricin to the White House and to New York City Mayor Michael Bloomberg.
2014	On March 21, 2014, Hatboro, Pennsylvania, US, 19-year-old Nicholas Todd Helman was arrested for sending a scratch-and-sniff birthday card laced with ricin to a man dating his ex-girlfriend. In 2015, he was sentenced to 20–40 years in prison.
2015	On July 29, 2015, 31-year-old Mohammed Ali from Liverpool, England was convicted of possessing a "chemical weapon." In January 2015, he attempted to purchase 500 mg of ricin on the "dark web." He was actually purchasing it from an undercover FBI agent. Ali said he was influenced by the television series "Breaking Bad."

Adapted from Frischknecht, 2008; Eitzen and Takafuji, 1997; Perry, 2009; Blinder, 2014; Williams, 2014; Palmer, 2015; BBC News, 2015.

a shift from nation-sponsored development to development through radical factions, individual criminals, and rogue nations.

US Bioterrorism Preparedness Controversies

Bioterrorism became a well-recognized part of American vernacular after five anthrax-tainted letters circulated on the East Coast of the United States in September and October 2001. The letters were responsible for 22 cases of anthrax disease and five deaths (Mina et al., 2002). These events led to serious consideration of other possible biological threats and led to strong debates on issues, such as who should receive smallpox or anthrax vaccinations and how available should antibiotics be to the general public for preparedness purposes. Federal, state, and local public health preparedness efforts accelerated to unprecedented levels in the years immediately following 2001, creating a new discipline and paradigm in the United States of addressing public health emergencies. Techniques, methods, and infrastructure developed and implemented for preparing for a bioterrorism attack are now used routinely for response to public health emergencies of many etiologies, including pandemic influenza. The integration of response paradigms into communicable disease and environmental health practices has built necessary skill sets and provided potential surge capacity. However, reduced funding for preparedness and funding shifts within other integrated and associated programs threatens the public health preparedness system as a whole. Balancing priorities while maintaining overall public health infrastructure continues to be a major policy challenge (ASTHO, 2008).

Another ethical concern for bioterrorism planning is the utilization of scarce resources. A bioterrorism event, with its inherent emotional and psychological stressors, will require a massive response, likely to be out of proportion to available resources of medical care, medical countermeasures, and perhaps infrastructure such as law enforcement. It is unlikely many cities or states will ever have enough resources to stockpile adequate supplies for everyone in need. Therefore, decisions will need to be made on how to distribute scare resources. Who has priority, how priorities will be determined, who will "enforce" priorities, and who will protect healthcare workers who make the decisions and follow the policies? These questions must be answered within the ethical framework of the community. Issues of equity, reciprocity, fairness, access, and accountability all must be addressed. Some states have adopted plans so each hospital has objective decision makers trained in the ethics of these difficult situations to guide healthcare workers in times of crisis (NCIOM, 2007).

Preparations for a bioterrorism event sometimes appear to be supporting a specific political agenda. Preparations for particular agents are based on intelligence suggesting one agent is more likely to be used than others. Manipulating the use of intelligence either by emphasizing it or deemphasizing it can affect response plans.

Biopreparedness research infrastructure could possibly increase the risks of future incidents. Concerns about security procedures and the extent of security procedures at university laboratories are frequently cited. Other safety and security problems have surfaced at the US Army Fort Detrick laboratories, as well as other research laboratories across the country (USGAO, 2008; Weiss and Snyder, 2002; Williamson, 2003). Research

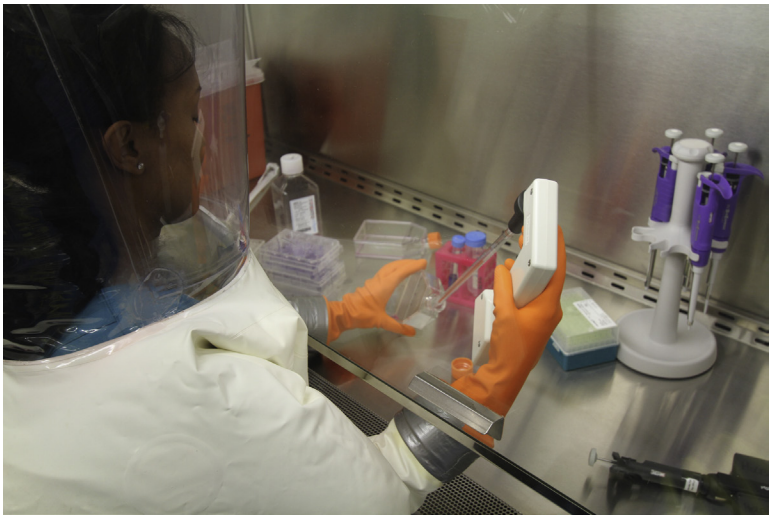


FIGURE 6-5 Scientists who work with highly infectious pathogens take extreme precautions in terms of Personal Protective Equipment and work in biocontainment labs, such as the Galveston National Lab at the University of Texas Medical Branch, where some of the world's most infectious diseases are studied and vaccines and therapeutics are developed. *Photograph courtesy of the Galveston National Laboratory.*

and development of defense measures constitute its own risk. Sufficient measures must be in place and enforced to ensure adequate screening and security in the life sciences industry, just as there are in other industries or initiatives. Again, a balance must be struck between supporting critical academic research and safety and security concerns (Fig. 6-5).

The law enforcement investigation of potential biocrimes is another unique aspect of bioterrorism preparedness and response that differs from a naturally occurring outbreak. However, determining if the occurrence is a crime or who the perpetrator of the crime may be is not easily discernible. Programs such as forensic epidemiology, which seek to train public health staff side by side with law enforcement officers, attempt to bridge the gap in language, skills, and approach. The public has different expectations of how health information is shared with healthcare workers than they do with law enforcement officers who may need sensitive patient information for a criminal investigation (CDC, 2002a). How information is shared and the legal and ethical considerations inherent in sharing information are key questions which must be worked out prior to an event. For example, to a healthcare provider the person affected is a "patient," to whom the healthcare provider has a relationship of individual advocacy and protection. A law enforcement officer sees the same person as a "victim" or a "perpetrator." Each of the law enforcement designations carries its own unique dynamic. Understanding these roles is critical in the coordination of an investigation.

Route of Infection and Chain of Transmission

The human routes of entry for bioterrorism agents depend upon the characteristics of the agent and the method of release. Some agents can only cause infection when

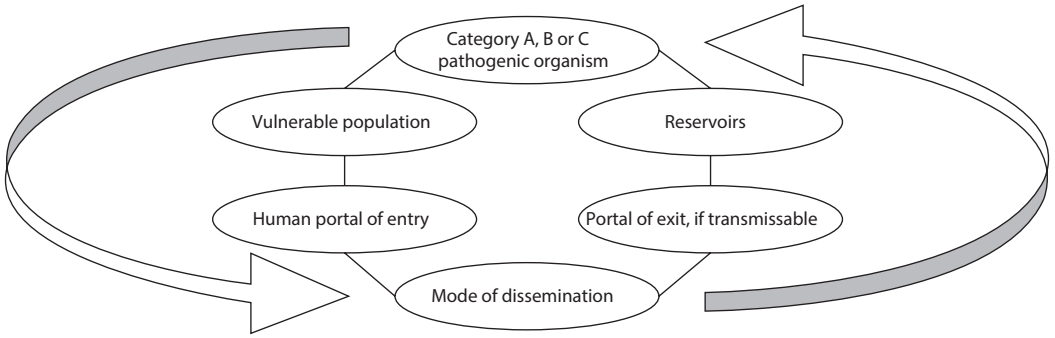


FIGURE 6-6 The bioterrorism chain of infection.

entering a specific portal of the body, whereas others cause different kinds of infections when entering through different portals. For example, *Bacillus anthracis* spores can be inhaled, causing inhalational anthrax disease, or can enter through a cut on the skin causing cutaneous anthrax disease. Though the agent is the same, the method of exposure results in very different disease conditions. There are also preferred portals of exit which influence the transmissibility of pathogenic organisms. Respiratory diseases usually exit an infectious person through the nose and mouth, whereas gastrointestinal infections exit through the GI tract. These organisms can be passed to other people through direct contact with symptomatic or asymptomatic human reservoirs of disease, or can sometimes be spread through living (nonhuman) or inanimate reservoirs (Fig. 6-6).

The goal of any bioterrorism infection control intervention is the same as many other infectious disease challenges. The chain of transmission must be broken. There are opportunities at every step of the infection process to break the chain and intervention may be required at multiple steps in the process. This includes reducing host susceptibility by boosting immunity through vaccination or drug therapy, blocking the portal of entry using personal protective equipment, or even destroying reservoirs which continue to sustain the infection process, such as mosquitoes or rodents.

At each link in this chain, there is the potential for tremendous variation. For example, across any vulnerable population, there will be a range of physiological responses among those exposed to a biothreat agent. This is due to a variety of complex environmental and immunological variables. A group of individuals receiving the same exposure to an organism will often display a broad assortment of responses. Some will not become infected at all, while others will become infected but display no symptoms. Others in the same cohort may display moderate symptoms, severe symptoms, or even die from their infection. These varying responses are due to differences in the exposures and the immune function of those exposed. Many factors influence these differences including age, physical condition, stress level, higher breathing rates which may increase the dose, and many other variables.

Categorization of Threats

Any bacteria, virus or biological toxin can be used to intentionally cause harm to others. Many common agents such as *Salmonella enterica* Typhimurium and *Shigella dysenteriae* type 2 can and have been used for intentional contamination of food (Kolavic et al., 1997). In 1999, a group of military and civilian experts were convened to narrow the list of possible biological threats and to prioritize them based on the potential impact they could have when used as a weapon. Evaluation of both open source literature as well as classified information resulted in a list of three categories of pathogens: Category A, B, and C (Rotz et al., 2002). Category A pathogens are high priority organisms and toxins posing the greatest threat to public health. This category includes agents causing the highest morbidity and mortality with a likelihood of subsequent public panic. They are capable of being disseminated over a large area and are sometimes transmitted easily from person-to-person. The scenarios associated with Category A agents necessitate extraordinary actions on the part of public health and healthcare organizations making them the focus of many public health preparedness activities. Throughout the early cold-war era of the 1950s and 1960s, most of these organisms were successfully weaponized in the offensive biological weapons programs of the United States and the former Soviet Union. Category B agents are fairly easy to disperse but have lower morbidity and mortality than the Category A agents. Public health response to Category B agents can be successfully managed through enhancing laboratory capabilities and epidemiological monitoring. Category C agents are emerging infectious organisms which could become easily available in the future and used as a weapon (CDC, 2007).

Critical Biological Agents for Public Health Preparedness: Disease (Biological Agent)

Category A

Anthrax (*Bacillus anthracis*)
Botulism (*Clostridium botulinum*, botulinum toxins)
Plague (*Yersinia pestis*)
Smallpox (*Variola major*)
Tularemia (*Francisella tularensis*)
Viral hemorrhagic fevers (Filoviruses and Arenaviruses: eg, *Ebola, Lassa Fever*)

Category B

Brucellosis (*Brucella* spp.)
Food safety threats (*Salmonella* spp., *Shigella* spp., *Escherichia coli* O157:H7)
Glanders (*Burkholderia mallei*)
Melioidosis (*Burkholderia pseudomallei*)
Psittacosis (*Chlamydia psittaci*)
Q fever (*Coxiella burnetii*)
Ricin toxin (*Ricinus communis*, from Castor Beans)
Staphylococcal enterotoxin B (Exotoxin from *Staphylococcus aureus* bacterium)

Continued

Critical Biological Agents for Public Health Preparedness: Disease (Biological Agent)—cont'd

Typhus fever (*Rickettsia prowazekii*)
Viral encephalitis (*Alphaviruses*: Venezuelan equine (VEE), eastern equine (EEE), and western equine encephalomyelitis (WEE) viruses)
Water safety threats (*Vibrio cholerae*, Cryptosporidium parvum)

Category C

Nipah virus encephalitis (Paramyxoviridae family)
Hendra virus encephalitis (Paramyxoviridae family)
Hantavirus pulmonary syndrome (Hantavirus)

Health Threats: Category A Organisms

Anthrax (*Bacillus anthracis*)

Anthrax disease is caused by the gram-positive, spore-forming bacterium *B. anthracis* (see Fig. 6-7). The disease occurs naturally among mammals such as cattle, sheep, goats, and camels. However, it can also occur in humans when exposed to infected animals or to weaponized anthrax spores. *Bacillus anthracis* is considered, by many biological warfare experts, to be the perfect biological weapon because of its ability to change into a spore when subjected to adverse environmental conditions which destroy other pathogenic organisms. Once in the spore form, *B. anthracis* can survive for decades under extreme hot or cold conditions. Historically, most cases of anthrax result from occupational exposures among leather and wool industry workers. The organism and disease get their name from the Greek word "anthrakitis," which is a kind of coal. The name originated from the appearance of cutaneous anthrax which causes a black lesion on the skin.

There are three forms of anthrax disease. These distinct disease presentations depend upon the route of exposure. Cutaneous anthrax is the most common form of anthrax disease and is fatal in about 5–20% of those who are not treated. It occurs following the exposure of compromised skin to anthrax spores. Inhalational anthrax disease is the most lethal form of the disease with more than 80% mortality for those who are not treated. It occurs following the inhalation of anthrax spores and is the most likely form of disease to be seen following an act of bioterrorism. Gastrointestinal anthrax disease is highly lethal but very rare. It usually occurs following the ingestion of live (nonspore) *B. anthracis* in contaminated, undercooked meat. Ingestion of the spore form of *B. anthracis* is unlikely to result in a fatal disease because of the transport time in the gastrointestinal system. The spores are likely to pass through the GI system before they have the opportunity to germinate. However, vegetative, nonspore *B. anthracis* organisms can rapidly begin to release toxins damaging the GI tract and can quickly cause illness when ingested.

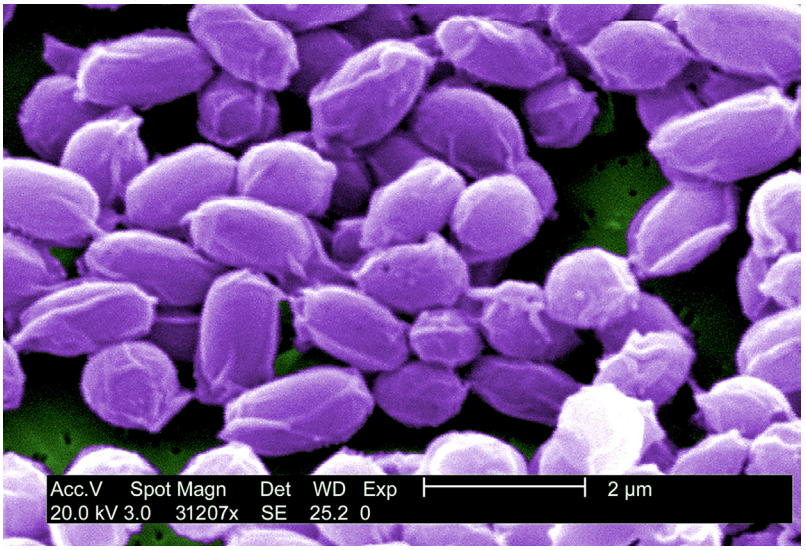


FIGURE 6-7 Under a very high magnification of 31,207×, this scanning electron micrograph (SEM) depicted spores from *Bacillus anthracis* Sterne strain bacteria. *Photo Courtesy of Centers for Disease Control and Prevention, Public Health Image Library.*

Cutaneous anthrax is the most common form of anthrax disease. It is a localized skin infection resulting from compromised skin exposure to anthrax spores. It is typically seen on commonly exposed skin such as the head, neck, hands, and arms. Areas of compromised skin, such as cuts, abrasions, or chronic dermatological conditions, are more prone to infection than intact skin. Once the spores become embedded in the skin, they germinate and begin to release a toxin. The toxin causes edema. The edema progresses into an ulcer over the course of several days and the ulcer develops into a depressed, painless lesion called an eschar (see Fig. 6-8). Though it is sometimes mistaken for a spider bite, the anthrax eschar remains painless whereas a spider bite causes severe pain. The eschar develops a black leathery appearance for a week or two and then loosens and falls off. Cutaneous anthrax is the most common form of occupational anthrax disease and may also result from an intentional release of spores. Cutaneous anthrax comprised 11 of the 22 cases of disease resulting from the 2001 anthrax letters. None of the cutaneous cases were fatal (Inglesby et al., 2002). If cutaneous anthrax is untreated, it may lead to a systemic disease with up to 20% mortality. If treated, this form of anthrax disease has very low (<1%) mortality (Lew, 1995).

Inhalational anthrax has the highest mortality of any form of anthrax disease. It results from inhaling a sufficient number of anthrax spores to initiate the disease process. This form of anthrax disease is very rare and even a single case requires notification of both public health and law enforcement authorities. In the 20 years preceding the 2001 anthrax attacks, there had not been a single case of inhalation anthrax in the United States (Inglesby et al., 2002). When anthrax spores are inhaled, they are transported by pulmonary macrophages, part of the lungs' defense system, to the mediastinal lymph nodes in the center of the chest.

FIGURE 6-8 Cutaneous anthrax lesion on the neck. *Photo courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Over a period of several days, the spores germinate into vegetative bacilli and begin to release toxins: lethal factor and edema toxin. Inhalational anthrax produces a two-stage illness including prodromal and fulminant phases. The prodromal phase lasts from a few hours to several days. It includes non-specific, flu-like symptoms including fever, malaise, shortness of breath, nonproductive cough, and nausea. This stage of the disease is easily confused with influenza or other non-specific infections. However, unlike many flu-like illnesses, inhalational anthrax does not normally include runny nose or sore throat (CDC, 2001). In addition, influenza does not normally include shortness of breath, vomiting, and mediastinal chest pain. These are common symptoms of inhalational anthrax. This prodromal period is sometimes followed by brief improvement before progressing to the next phase of illness. The second phase is a high-grade bacteremia called the fulminant stage. It includes symptoms such as fever, respiratory distress, profuse sweating, cyanosis, and shock. Patients displaying these symptoms usually progress quickly to death. If an outbreak is known or suspected, initial diagnosis of inhalational anthrax is made using the described signs and symptoms. A widened mediastinum on a chest X-ray, as displayed in Fig. 6-9, is considered highly suspect for inhalational anthrax. However, this clue may or may not be present at the initial patient evaluation. A widened mediastinum can also result from other respiratory conditions making diagnosis difficult. In the 2001 inhalational anthrax cases resulting from the anthrax letters, all patients had abnormal chest X-rays including infiltrates, effusions and widened mediastinum (Jernigan et al., 2001). Confirmation testing may be accomplished using blood cultures and polymerase chain reaction (PCR) of blood or pleural fluid.

FIGURE 6-9 Chest radiograph 22 hours prior to death showing widened mediastinum due to inhalation anthrax. *Photo courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

The gastrointestinal form of anthrax is caused by the ingestion of vegetative *B. anthracis*. This may occur from consumption of undercooked contaminated meat from an infected animal and can be very difficult to diagnose. Initial presentation may include nausea and vomiting quickly progressing to bloody diarrhea and sepsis. It can lead to the same sort of fatal sepsis as untreated cutaneous and inhalational anthrax. Although gastrointestinal anthrax may result from an intentional release of anthrax, the spore form of anthrax is far less likely to generate gastrointestinal cases (Inglesby et al., 2002).

Treatment recommendations for inhalational anthrax are based on animal testing and a very small number of human cases. Antibiotic therapy should be initiated as soon as possible when exposure is suspected. The 2001 anthrax cases included 11 inhalational anthrax cases. Six survived due to the rapid initiation of multiple antibiotic therapies and aggressive supportive care (Jernigan et al., 2001). If an epidemiological or criminal investigation identifies populations at risk, post-exposure prophylaxis should be provided to all potentially exposed persons. If the right antibiotics are administered quickly enough, especially before symptoms begin, the disease can be prevented. This is the greatest challenge in managing a mass exposure to *B. anthracis*. Getting the right antibiotics into the exposed population quickly enough to halt the progression from exposure to disease is very difficult. Although patient contacts (eg, family, friends, healthcare providers) and others not

originally exposed to a *B. anthracis* release do not require prophylaxis, there are likely to be difficulties in definitively identifying all at risk, particularly if it is an aerosolized urban release scenario. Between the need to expand the potential exposure footprint to include everyone at risk and the demands of the "worried well" not necessarily at risk but who insist upon prophylaxis, the list of those receiving prophylactic antibiotics may easily be in the hundreds of thousands within a 2- to 3-day timeframe.

The greatest short-term challenge in managing a response to a large scale anthrax release is the identification and prophylaxis of the entire population at risk. Although this preparedness scenario has been exercised by most major US cities, these exercises have shown there is insufficient capacity to provide prophylaxis to the entire population. Through exercises, many known gaps have been identified and addressed but many more either have no solution or are simply unknown. This kind of mass prophylaxis has never been done before on this scale. The long-term challenges may even prove to be greater. It will require the safe and complete remediation of a contaminated urban area. Although the inside remediation of several anthrax contaminated buildings has been accomplished, a wide area urban restoration project has never been done.

Post-exposure prophylaxis (PEP) of inhalational anthrax consists largely of antibiotics, augmented with vaccine. The antibiotics currently approved in the US include ciprofloxacin, levofloxacin, and doxycycline for adults 18 years and older. There is no safety data available for levofloxacin use beyond 30 days. Therefore, oral ciprofloxacin and doxycycline are recommended as first-line antimicrobial drugs for PEP. If first-line agents are not tolerated or are unavailable, levofloxacin and moxifloxacin, amoxicillin and penicillin VK if the isolate is penicillin susceptible, and clindamycin may be substituted (Hendricks et al., 2014).

There is a licensed, cell-free anthrax vaccine called Biothrax (Anthrax Vaccine Adsorbed) manufactured by Emergent Biosolutions (formerly BioPort) in Lansing, Michigan, the only current US manufacturer of anthrax vaccine. Use of this vaccine has been restricted to military personnel and to groups with occupational exposure risks, including lab personnel required to handle suspicious powders for testing, and veterinarians or others exposed to potentially contaminated animals or animal products (Emergent Biosolutions, 2002). However, in the US, the vaccine is not approved for use after exposure. If a decision is made to mass vaccinate for post-exposure prophylaxis, it would be done so under an investigational new drug or emergency use authorization. The Advisory Committee on Immunization Practices (ACIP) recommends using anthrax vaccine in combination with a prophylactic antimicrobial regimen to reduce the recommended time of antibiotic therapy from 60 to 30 days. This includes a three-dose vaccine regimen (0, 2, and 4 weeks) in combination with 30 days of antimicrobial prophylaxis (CDC, 2002b). Following the mailed anthrax incidents of 2001, more than

10,000 people were placed on a 60-day regimen of antibiotic therapy. However, adherence to the full 60-day antibiotic regimen was low. Less than half (42%) of the individuals placed on this prophylactic therapy were able to complete the course (Shepard et al., 2002). Combining anthrax vaccinations with antimicrobial prophylaxis may shorten the necessary course of prophylactic therapy and may facilitate complete prophylaxis for those at risk.

Those at greatest risk of infection are individuals exposed to the initial release of anthrax spores. Depending upon the weather and other environmental conditions, the spores will usually settle within several hours. They will then pose ongoing risks of secondary aerosolization from passing foot traffic, vehicles, and other disruptions. If a *B. anthracis* release occurs in an urban area, the environmental decontamination of surfaces will be a complicated and extremely expensive process. The clean-up will last for years and require many millions of dollars in direct cost. This is in addition to the high costs of business disruption and the personal impact of possible loss of life and required abandonment of property for years during clean-up. The social impact will be far reaching.

Exposed individual and patient decontamination for *B. anthracis* is only warranted in the immediate aftermath of a known release. Human decontamination simply consists of clothing removal and a soap and water shower. Bleach and other harsh chemicals are not necessary. It is improbable a release would be detected for at least 24 hours. During that time, those exposed will likely change clothes and shower. The chances of mass *B. anthracis* decontamination are remote. If a covert release is successfully accomplished, patients seen days or weeks later will also not pose a risk to providers and do not require decontamination. Ill patients with cutaneous anthrax require contact precautions but inhalational anthrax is not spread person-to-person.

Botulism (*Clostridium botulinum* Toxin)

Botulism is caused by neurotoxins produced by the anaerobic, spore-forming, gram-positive *bacillus C. botulinum*. This family of botulinum toxins cause paralytic disease and are regarded as the most potent poisons in the world (Gill, 1982). There are three forms of botulism disease including foodborne, wound, and infant (also called intestinal) botulism. Foodborne botulism results from ingesting the toxin in contaminated food. It causes descending paralysis that can lead to respiratory failure and death. Wound botulism occurs when a wound is contaminated with *C. botulinum*. This form of botulism disease is commonly associated with injected drug use or traumatic injury. Infant (intestinal) botulism occurs when susceptible infants ingest *C. botulinum* spores in food. Illness results in difficulty feeding, constipation, weakness, and muscle hypotonia, also called "floppy baby syndrome." (see Fig. 6-10) There are eight separate *C. botulinum* toxin types, including A, B, C alpha, C beta, D, E, F, and G. All these types except two (C alpha and D) cause botulism in humans. Botulinum toxin could be used as a weapon of terror to contaminate water or food supplies or could be delivered as an aerosol. If an aerosol release is used, symptoms are likely to be similar to food botulism with a delayed onset. Although there have been no

FIGURE 6-10 Six-week old infant with botulism that is evident as a marked loss of muscle tone, especially in the region of the head and neck. *Photo courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

documented human inhalational botulinum cases, animal studies have shown that aerosolized botulinum toxin can be absorbed by the lung (Shapiro et al., 1998). *Clostridium botulinum* is the only toxin listed as a Category A biological agent by the CDC. The other five Category A agents are actual bacterial or viral agents. This toxin earned a place near the top of the threat list because of widespread availability and tremendous potency as a biological poison.

There are cases of botulism which occur naturally because of improper canning and food handling. Across the US, fewer than 200 cases typically occur each year (CDC, 1998). Foodborne botulism is the most common form of botulism disease and is caused by eating foods contaminated with *C. botulinum* which has released toxins. If intentional food contamination becomes the delivery method selected by a terrorist or criminal, it would likely be limited to a small-scale attack. The toxin is easily destroyed with normal cooking and is not stable enough to survive for long time periods in bulk food items. Regardless of the size or source of a botulism outbreak, any cases are considered to be a public health emergency which must be reported and investigated immediately.

Intestinal botulism occurs when *C. botulinum* spores are ingested resulting in intestinal colonization. The germinating spores release the illness-causing toxin. This form

of the disease typically occurs in infants and had been attributed to using honey to get infants to suck on a nipple. Although adults have immune systems able to tolerate and manage the minuscule number of botulinum spores which often exist in honey, children under the age of two years do not. However, in children or adults, when an infected wound is not apparent and a specific food source cannot be identified, it is typically attributed to intestinal colonization. If an infected wound is observed, it may be wound botulism. This form of disease occurs when *C. botulinum* infects a wound, the wound is partially closed causing low oxygen environment, the bacteria thrives, and releases the toxin causing systemic illness. Foodborne, intestinal, and wound botulism occur naturally. However, the fourth type of disease, inhalational botulism, does not occur naturally and is the most likely form expected to result from an intentional aerosolized botulinum toxin release.

The onset of botulism symptoms depends upon the exposure dose. Incubation for foodborne botulism ranges from several hours to just over a week (St. Louis et al., 1988). The lack of human data on inhalational botulism disease progression makes it impossible to predict exactly how these cases may progress. Initial botulism symptoms from any source include blurred vision and dry mouth. For small exposures, these symptoms may be all the symptoms a patient experiences before recovery. Significant exposures may include slurred speech, difficulty swallowing, and descending peripheral muscle weakness. Severe disease involves the respiratory muscles, leading to respiratory failure and death. Presumptive diagnosis is based on the descending paralytic symptoms described. This diagnosis may be confirmed through testing available at reference labs, but takes several days to complete. Botulism is sometimes mistaken for Guillain-Barré syndrome, myasthenia gravis, or other diseases of the central nervous system (CNS) but differs from other CNS conditions in the descending symmetrical paralysis and absence of sensory nerve damage (Arnon et al., 2001).

The greatest challenge in managing a response to a large scale botulism outbreak will likely be a shortage of ventilators. As the descending paralysis moves down from the top of the head to the neck and chest of those exposed, it will eventually cause respiratory failure and require mechanical ventilation to maintain respiration.

Botulism treatment requires supportive care with careful respiratory support and rapid administration of antitoxin. It is not transmitted from person to person, so patient care does not include a negative pressure patient room. In a mass exposure, these therapies pose tremendous challenges to an effective response. The need for ventilators may quickly exceed available capacity in an affected community. In addition, the antitoxin efficacy is dependent upon how early it is started in the course of treatment (Tackett et al., 1984). This highlights the need for well-trained healthcare providers who maintain a high index of suspicion. It also shows how important it is to maintain a logistical system which can rapidly

deliver antitoxin anywhere it is needed. The Centers for Disease Control and Prevention maintains an antitoxin supply and will release it for use through state health departments following a quick consultation. The botulism antitoxin cannot be used prophylactically for exposed individuals. It can only be used when initial symptoms appear. Although there is no botulism vaccine available, there are some promising advances. Human Botulism Immune Globulin Intravenous (BIG-IV) has been approved for use in infants under the age of 1 for type A and B botulinum toxin, reducing the length of treatment (Arnon et al., 2006). This could become the basis of new therapies for other forms of botulism disease as well.

Plague (*Yersinia pestis*)

The word "plague" is often used to describe lethal outbreaks from a variety of infectious organisms. However, it is a specific disease resulting from an infection by the gram-negative *bacillus, Y. pestis*. Plague has an infamous history killing millions of people in pandemic outbreaks occurring around the world across the centuries. Plague is a disease caused by *Y. pestis*, an anaerobic, gram-negative bacterium. The natural host for this organism is a rat and the disease is usually transmitted to humans through the bite of a flea which has fed on an infected rodent. There are about 10–15 human plague cases annually which naturally occur this way in the Western United States. Many human cases also naturally occur in portions of South America, Africa, and Asia. Between 1000 and 3000 cases occur globally each year (CDC, 2009). Since plague still occurs naturally in many parts of the world, it is important to understand the baseline occurrence of naturally occurring plague so suspicious cases can be recognized. If human cases are identified in a non-endemic area, in persons without risk factors, or in the absence of confirmed rodent cases, a terrorist release of *Y. pestis* should be considered as a possibility. There are three types of plague disease manifestations, including bubonic, pneumonic, and septicemic. The bubonic form of plague is the most likely form of the disease to be seen from naturally occurring infections. An aerosolized release is the more likely terrorist scenario resulting in the pneumonic form of the disease.

Sustained person-to-person transmission is possible through airborne droplets from infected individuals. This potential secondary transmission complicates the management of a large bioterrorism related outbreak and poses significant infection control challenges. Untreated pneumonic plague has a mortality rate of nearly 100%. All forms of plague can progress to the septicemic or pneumonic forms of the disease. The worst case bioterrorism scenario would be an aerosolized release of *Y. pestis* causing a large number of primary cases which continue to spread the infection to others before it is brought under control through public health interventions.

Yersinia pestis was isolated and characterized by Alexandre Yersin who traveled to Hong Kong in 1894 to study a plague outbreak that had taken tens of thousands of Chinese lives. The disease was eventually named after him. He seldom used his first name, referring to himself simply

as Yersin and he refused to attend most medical and scientific meetings of his day. He was an explorer and traveler trained in Europe who was fascinated by "Indo-China." After discovering *Y. pestis*, he went on to become the founder and director of the Medical School of Hanoi (Bibel and Chen, 1976).

As previously mentioned, there are three forms of plague disease: pneumonic, bubonic, and septicemic. Early symptoms for all forms of plague disease include classic flu-like symptoms such as fever, chills, myalgia, weakness, and headaches. Each form of plague poses different challenges and unique symptoms.

Pneumonic plague is the least common and most severe form of the plague disease. This form of disease results from the inhalation of infectious particles either from an intentional aerosolized release or from the cough of an infectious person. *Yersinia pestis* can only remain viable for about an hour as an aerosol and will quickly die when exposed to sunlight and heat outside of a living host. After exposure to aerosolized *Y. pestis*, individuals will display symptoms in 1–6 days (Inglesby et al., 2000). Based on limited epidemiological data, the mortality rate for pneumonic plague in the United States is about 57% (CDC, 1997). Patients will initially present with dizziness, chest discomfort, and a productive cough with blood-tinged sputum. By the second day, the symptoms may rapidly worsen and include chest pain, coughing, sputum increase and may include dyspnea, hemoptysis, cardiopulmonary complications, and circulatory collapse.

Bubonic plague is the most common form of naturally occurring disease. It is spread through the bite of an infected flea or by handling contaminated infected animals. Although this form of plague is less likely to be the result of bioterrorism, it is possible to intentionally spread bubonic plague through an intentional release of infected fleas. The mortality rate for this form of the disease is approximately 13% (CDC, 1997). Patients with bubonic plague will present with swollen, tender, and painful buboes (enlarged lymph nodes). These symptoms typically occur within 24 hours of the onset of early flu-like symptoms and are generally located near the area of inoculation. Most frequently, buboes occur in the inguinal or femoral lymph node region of the groin (see Fig. 6-11). Buboes may erupt on their own. Incision and drainage of an infected bubo may result in aerosolization of bacteria and should be avoided.

Septicemic plague is the least common form of disease and can result from either pneumonic or bubonic disease. It is a systemic infection resulting from introduction of *Y. pestis* into the bloodstream. The mortality rate for this form of the disease is about 22% (CDC, 1997). Patients with septicemic plague will initially present with nausea, vomiting, and diarrhea and may develop skin lesions, gangrene, and necrosis later in the infection process.

Rapid diagnosis and treatment is essential to reduce plague morbidity and mortality. Without quick antibiotic treatment, plague can cause death in several days. Initial diagnosis can be accomplished through microscopic examination of clinical samples of lymph node aspirates, sputum, or spinal fluid. Definitive diagnosis is accomplished using sputum

FIGURE 6-11 This plague patient is displaying a swollen, ruptured inguinal lymph node, or bubo. *Photo courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

or bubo cultures, or IgM and IgG antibody laboratory testing. In addition, it is important to identify antibiotic resistance patterns to select the most effective treatment. Rapid diagnosis and antibiotic therapy are the keys to successfully managing a plague outbreak. Once known or suspected cases of pneumonic plague occur, assume all patients presenting with flu-like symptoms are positive and treat them immediately. The rapid progression of the disease does not allow much time for definitive diagnosis during a possible mass exposure or outbreak. The antibiotic selection is based on the results of susceptibility testing and the age and condition of the patient. The aim of treatment includes both the treatment of active disease and the prophylactic treatment of suspected exposures. There was a killed whole-cell vaccine for use against bubonic plague but the vaccine was not very effective and has been discontinued. There are several research initiatives currently under way to develop a new plague vaccine.

Any identified cases of plague must be reported to public health authorities. In the US, if an intentional release is suspected, local law enforcement and the Federal Bureau of Investigation (FBI) must also be notified. As the response is initiated, infection control for bubonic and septicemic forms of plague disease will consist of standard infection control precautions. If pneumonic plague is identified, it requires patient isolation and droplet precautions until the patient has been on antibiotic therapy for at least 48 hours and shows signs of improvement.

Smallpox (*Variola Major*, *Variola Minor*)

Smallpox disease is the most destructive infectious disease in human history. It has claimed more human lives than any other pathogen. It is caused by variola viruses, which

are members of the orthopoxvirus family and it can only survive in humans. Smallpox was eradicated in the 1970s through a World Health Organization vaccination campaign. Since being declared eradicated over three decades ago, it now only exists in the government research labs of Moscow, Russia, and at the CDC in Atlanta, Georgia. Unfortunately, there are suspicions not all nations destroyed their lab samples of the organisms. If a rogue nation still has virus and supplies it to a terrorist organization, it could cause a devastating blow to international public health. For that reason, any single confirmed case today is considered an international public health emergency.

There are two forms of this virus including *V. major* and *V. minor*. *Variola major* is the most likely form of the organism to be used as a weapon and is the causative agent for classic smallpox disease. It was the most common form of disease seen in historical epidemics and has a mortality of about 30%. *Variola minor* is a less common organism with a very low mortality rate of less than 1% (Fenner et al., 1988). The viruses are transmitted person to person through inhalation or direct contact with viral particles spread by infected individuals through their respiratory secretions or from pustules or scabs on their skin. Once an individual is exposed, an asymptomatic incubation period of approximately two weeks follows. This incubation period is followed by a flu-like, prodromal illness for 2–5 days. Near the end of this prodromal period, the infected individual begins to develop pustules in the throat and mouth. They are then infectious, before any pustules appear on the skin. Once a rash begins on the skin, it has a characteristic, centrifugal pattern appearing mostly on the face, arms, and legs with fewer pustules on the trunk. It quickly becomes papular, then pustular, and then scabs over. The scabs separate in 2–3 weeks. For those who do not survive, death often comes in the second week of this stage. If the patient survives, the loss of the scabs is the end of their infectiousness. Survivors have a variety of complications, including severe scarring, encephalitis, secondary bacterial infections, conjunctivitis, and blindness.

During a confirmed smallpox outbreak, diagnosis should be made based on the clinical presentation alone. The greatest challenge will be the diagnosis of an index case. Most healthcare workers have never seen a smallpox case and many may miss the initial diagnosis. The most similar patient presentation is chickenpox. Smallpox lesions begin in the mouth and throat and then spread to the face and extremities. The lesions are concentrated centrifugally on the face, arms, and legs (see Fig. 6-12). In addition, the lesions appear on the palms of the hands and the soles of the feet. Across the body, the lesions are uniform and in the same stage of development (vesicles, pustules, or scabs). In contrast, chickenpox concentrates centrally on the trunk, not centrifugally. The chickenpox lesions are not generally seen on the palms of the hands or the soles of the feet and are not uniform in appearance. Chickenpox lesions are usually in various stages of development with pustules erupting next to scabs.

Smallpox is contagious by person to person transmission and usually spreads through respiratory droplets or direct contact with infected persons or contaminated materials. Historically, each primary case infects three to four more people. The exception to this is if infected individuals have a severe cough, they may infect dozens of other susceptible

FIGURE 6-12 A young boy in Bangladesh with the classic maculopapular rash evident on his torso, arms, and face in 1974. *Photo courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

contacts (Wehrle et al., 1970). Those at highest risk of secondary infection include household contacts and healthcare providers. In a healthcare setting, airborne and contact precautions must be instituted. The patient should be in a negative pressure room and personnel providing care must wear the proper respiratory protection as well as other appropriate personal protective equipment. All suspected cases should be immediately isolated and observed. Confirmed cases should remain in hospital isolation until all the scabs separate. Home isolation may be the only option during a large outbreak. Over a century ago, there were separate hospitals designated for smallpox patients to segregate them from other healthcare facilities. Anyone identified as a contact of a smallpox case should be vaccinated immediately and then monitored twice daily for 17 days for fever. If a fever greater than 38°C (>101°F) develops, it could be the prodromal stage of smallpox and the patient should be isolated (Fenner et al., 1988).

Smallpox vaccine does not contain Variola virus. It contains an attenuated-strain of vaccinia virus, a close cousin of Variola. It is genetically similar enough to smallpox a

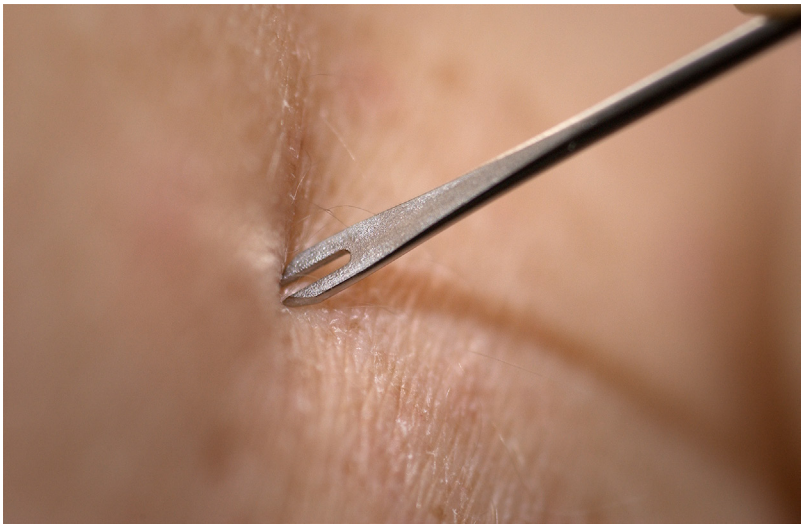


FIGURE 6-13 CDC clinician demonstrates the use of a bifurcated needle during the 2002 Smallpox Vaccinator Workshop. *Photo by James Gathany, courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

small vaccinia infection on the skin resulting from the vaccination will provide protection against smallpox as well. The original vaccine, Dryvax, was made from freeze-dried calf lymph and is no longer produced. The decades old stockpile of this vaccine was used in the US by the military and for homeland security initiatives for many years but in 2007 the Food and Drug Administration approved the next generation of smallpox vaccine. It is very similar to the old vaccine as it is still delivered with a bifurcated needle to initiate a vaccinia skin infection (Fig. 6-13). It is called ACAM2000 and the primary difference is in the production process. This newer vaccine is made using cell cultures (FDA, 2013). Although it will have fewer side effects than the original vaccine, there are serious risks of complications with the vaccine and it should not be offered to the general public unless there is an imminent threat of a smallpox attack or outbreak. Research continues toward developing a safer smallpox vaccine.

Vaccination may also be used prophylactically to reduce morbidity and mortality. It has proven effective when provided within 4 days of exposure (Dixon, 1962). An exposure is defined as suspected inhalation of viral particles from an initial bioterrorism release, face-to-face contact with a confirmed smallpox case, or direct contact with potentially contaminated materials or lab specimens. Other antiviral drugs, such as Cidofovir, may also improve patient outcomes if given within 1–2 days of an exposure (Huggins et al., 2001). However, it is impossible to say which prophylactic options may be most effective for humans in the absence of existing smallpox cases and exposures.

There are three smallpox disease variants. Each disease type is identified by the presentation of the rash. Classical smallpox is the most common and historically accounts for >90% of cases (Henderson et al., 1999). The other types of smallpox disease are malignant and hemorrhagic. These types appear much different than typical smallpox and are difficult

to diagnose. Malignant smallpox cases have a velvety, non-pustule rash which is associated with high mortality. Hemorrhagic smallpox looks like a diffuse erythematous rash leading to petechiae and hemorrhages. It was often misdiagnosed as meningococcemia and was also usually fatal. One of the planning challenges in preparing for the possibility of a smallpox attack is the question of how initial patients may present symptoms. As assumptions about *V. major* infections are based on the natural presentation of smallpox disease, it may be easy to misdiagnose individuals infected from an aerosolized inhalation exposure resulting in a large number of individuals with atypical presentations.

Fortunately, variola viruses are not stable or persistent in the environment. If they are released as an aerosol, the virons will be naturally inactivated within about 24 hours. Because the organism dies rapidly in the external environment, buildings and areas in the path of an intentional release do not need decontamination and no long-term environmental recovery issues will follow a release (Henderson et al., 1999).

Tularemia (*Francisella tularensis*)

Tularemia is caused by *F. tularensis*, a very hardy and highly infectious aerobic organism. Exposure to as little as 10 organisms can result in the disease, also known as "rabbit fever" or "deer fly fever" (Saslaw et al., 1961). Naturally occurring disease is almost always rural. It has occurred in every US state except Hawaii but primarily occurs in the Midwest. It usually occurs as individual cases or as small, isolated outbreaks and has never been reported as a large epidemic. However, the infectiousness and availability of the organism makes it a potential weapon for terrorists. Any cases in urban or non-endemic areas, or among populations without clear risk factors, should be investigated as a possible bioterrorism incident.

Humans become infected by *F. tularensis* in a several ways. As with other Category A organisms, the route of exposure plays an important role in determining the presentation of tularemia disease. It is a very complex disease which presents as pneumonic, typhoidal, ulceroglandular, glandular, oculoglandular, or oropharyngeal. Natural infections usually occur from handling infected small mammals, such as rabbits or rodents, or through the bites of ticks, deerflies, or mosquitoes carrying the infection from feeding on infected animals. Most of these natural infections are ulceroglandular tularemia. If an infected animal is eaten without being thoroughly cooked, or if contaminated food or water is ingested, it may cause oropharyngeal tularemia. It is also possible to get the organism on the hands and to inoculate the eyes resulting in oculoglandular tularemia. The types of tularemia disease likely to result from an intentional aerosol release of *F. tularensis* are pneumonic and typhoidal tularemia. Morbidity and mortality vary greatly depending upon the type of tularemia disease. The most common forms of the disease, such as ulceroglandular tularemia (50–85% of all cases), have a low mortality of less than 2% (see Fig. 6-14) (Dennis, 1998). However, primary pneumonic cases have a much higher mortality of 30–60% if untreated (Evans et al., 1985).

Francisella tularensis inhalation usually causes flu-like symptoms after a 2–5 day incubation period. However, these symptoms can occur as soon as one day or as long as 14 days after exposure (Dennis et al., 2001). The flu-like clinical presentation may

FIGURE 6-14 Girl with ulcerating lymphadenitis colli due to tularemia, Kosovo, April 2000. *Photo courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

include the rapid onset of fever, chills, myalgia, weakness, and headaches. These symptoms may worsen to include a nonproductive cough, sore throat, and inflammation of the bronchi, lungs, and lymph nodes. Diagnosis is complicated as access to rapid diagnostics for tularemia is limited. Although there are promising initiatives under way to develop this capability, the initial identification of an intentional tularemia outbreak will depend upon an astute physician using a presumptive diagnosis based on the clinical presentation. This is particularly difficult for clinicians who have never seen a case. If a large number of otherwise healthy individuals present with these symptoms, particularly in non-rural regions, the index of suspicion should be high for an intentional release of *F. tularensis*. If inhalational tularemia is suspected, respiratory secretions and blood samples can be used for confirmatory testing. If a case of pneumonic tularemia is suspected or confirmed, providers should assume all patients presenting with flu-like symptoms are positive and treat appropriately with antibiotics. The antimicrobial selection is based upon the results of susceptibility testing, the age and condition of the patient, and the goal of the therapy. The goal may be treatment of suspected disease or prophylactic antimicrobial treatment for suspected exposures. A vaccine also exists for tularemia which uses an attenuated live vaccine strain (LVS) (Oyston and Quarry, 2005);

however, the vaccine is not available. The strain used and the process of attenuating it have raised safety and efficacy questions.

Francisella tularensis can survive for long periods of time in a cool, moist environment. However, it is unlikely to survive for a long-period of time in an outdoor environment following an aerosol release. It is also not likely to be reaerosolized. Therefore, environmental decontamination following aerosol release of *F. tularensis* is not necessary. Individuals suspected of being contaminated by an aerosol should launder clothing and shower with soap and water. Even though *F. tularensis* is highly infectious for individuals directly exposed to the organisms, it is not spread from person to person.

Viral Hemorrhagic Fevers (Filoviruses, Arenaviruses, Bunyaviruses, and Flaviviruses)

The term "viral hemorrhagic fevers" (VHFs) describes a severe multisystem syndrome caused by one of four different viral families (Arenaviruses, Filoviruses, Bunyaviruses, and Flaviviruses). These are all RNA viruses with natural animal reservoirs and arthropod vectors. These hosts usually include rats. Transmission to humans typically results from infected hosts or vectors exposing humans through their body fluids and excretions. Some VHF viruses can spread from person to person through close contact with infected people or exposure to their body fluids. VHF illness begins as flu-like symptoms including fever, fatigue, dizziness, muscle aches, and weakness. The symptoms become worse as vascular damage takes place. As the disease progresses, severe symptoms occur including hypotension, facial edema, pulmonary edema, and mucosal hemorrhages. Some patients will bleed from body orifices, internal organs, or under the skin. Although the bleeding is sometimes severe, it is rarely the cause of death. VHF death is usually the result of multiorgan failure and cardiovascular collapse. The case fatality rates for VHFs have a wide range which differs by organism and by outbreak. For example, the case fatality rate was only 0.5% for an Omsk hemorrhagic fever outbreak but as high as 90% for a Zaire Ebola outbreak (Cunha, 2000; Muyembe-Tamfum et al., 1999). These organisms are not typically transmitted through airborne routes in natural outbreaks, but there is concern the virons may be delivered as an aerosol during a bioterrorism attack. If a particularly infectious and lethal VHF agent is used for an aerosol attack, it could be devastating.

The RNA viruses causing VHFs are dependent upon animal and insect hosts for their survival, and the naturally occurring forms of these diseases are limited to the area immediately surrounding their primary hosts. Humans are not normally part of their lifecycle but are sometimes inadvertently included by encountering an animal reservoir or infectious vector. Outbreaks are erratic and unpredictable but usually isolated.

VHF pathogens were placed on the Category A list of threats because of their potential lethality and infectiousness at low doses when delivered as an aerosol. Although there has never been an aerosolized VHF attack, animal studies have demonstrated the severe risk of infection posed by aerosolization of these pathogens (Johnson et al., 1995; Stephenson et al., 1984). In this attack scenario, there will be an incubation period

FIGURE 6-15 This image depicts some of Guinea's frontline healthcare workers receiving practical training in identifying, isolating, and caring for suspected Ebola patients, and protecting themselves during the 2014 Ebola outbreak. *Photo by Lindsey Horton courtesy of the Centers for Disease Control and Prevention (CDC).*

ranging from a couple days to three weeks depending on the VHF pathogen used, the individual dose received, and other variables. A prodromal illness of flu-like symptoms occurs for about one week. Severe infections may also display bleeding from orifices, under the skin, and in internal organs, eventually leading to multi-organ failure. Initial diagnosis is based on the clinical presentation and requires a high clinical index of suspicion (Borio et al., 2002). Treatment is limited mostly to supportive care. There are no antivirals specifically approved for VHF illnesses and the effectiveness of antivirals is not known.

Those at greatest risk during historical outbreaks have been healthcare workers. To ensure worker safety, infection control precautions must be strictly enforced with suspect VHF patients. This includes patient isolation in a negative pressure room, strict hand hygiene, and use of double gloves, impermeable gown, face shield, eye protection, and leg/shoe coverings (see Fig. 6-15). In addition, HEPA respiratory protection should be worn by anyone entering the patients room (Borio et al., 2002). The risk to prehospital contacts may be somewhat lower because the patients will likely be in the earlier stages of disease and less infectious.

Prevention and Detection

Preventing bioterrorism threats begins with solid regulations to prevent acquisition of pathogens through strict control of potential biothreat agents, rapid detection of

pathogenic releases, early identification of individual cases and outbreaks, and protection of susceptible populations through a strong public health and medical preparedness infrastructure. In an effort to shore up these capabilities, the US government passed a variety of preparedness promoting legislation beginning with the Public Health Security and Bioterrorism Preparedness and Response act of 2002 (USC, 2002). This act was divided into five sections and was designed to address the most pressing bioterrorism threats identified following the 2001 anthrax letters.

Public Health Security and Bioterrorism Preparedness and Response Act of 2002, Five Sections.

Title I: National Preparedness for Bioterrorism and Other Public Health Emergencies
Title II: Enhancing Controls on Dangerous Biological Agents and Toxins
Title III: Protecting Safety and Security of Food and Drug Supply
Title IV: Drinking Water Security and Safety
Title V: Additional Provisions

The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 began a funding stream which strengthened overall public health preparedness for bioterrorism and a variety of other threats. Title I provided much needed resources to both the Department of Health and Human Services and the Centers for Disease Control and Prevention. It also accelerated work on the Strategic National Stockpile and provided funding to state and local health departments and local hospitals for enhanced preparedness initiatives. Title II created controls over pathogenic agents and toxins, making them more difficult to acquire. This included overlapping regulatory authority by USDA and DHHS to control organisms which pose threats to plants, animals, and humans. This included a requirement for registration by anyone possessing hazardous biological material (so-called "select agents") and it established strict controls for safety and security. Title III was established to protect food and drugs. It included enhanced inspection of imported foods, food safety and security, and upgrading of animal and plant health inspections. Title IV increased security requirements for drinking water, and Title V included several additional provisions primarily directed toward prescription drugs.

The laws instituted through the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 to control pathogenic organisms were not only a result of the 2001 anthrax letters but in part a response to the exploits of microbiologist Larry Wayne Harris. He mail ordered and received pathogenic organisms. It was discovered later that he had ties to white supremacist groups and allegedly threatened to carry out an "anthrax release" in Las Vegas. Although the strain he purchased was a harmless strain of *B. anthracis* spores used in vaccine development, it highlighted a vulnerability that needed to be addressed.

In 2005, another major piece of public health legislation was passed. The Pandemic and All-Hazards Preparedness Act (PAHPA) was a response to growing public concerns over pandemic influenza. PAHPA and its reauthorization in 2014 continue to stress the balance between preparedness activities and core public health infrastructure. More details on these bills are included in Chapter 1, Public Health Preparedness History and Policy.

Cultivating the Perceptive Provider

Limiting the impact of a bioterrorism attack requires diligent healthcare providers with sufficient training and support. Over an extended period of time, and in the absence of recent attacks, this diligence becomes difficult to maintain. There are nonbioterrorism threats encountered regularly that draw the focus away from preparedness for high consequence, unlikely events. Though understandable, it will not be excusable if a sentinel case is missed. The diversity of terrorist threats has resulted in substantial investments in public health and healthcare preparedness. The US costs for preparedness activities are well into the billions and are likely to continue for many years. Much of this spending takes the form of high-tech solutions including new epidemiological surveillance software or new detection and monitoring devices, such as the BioWatch Program. Although this technology may compliment other preparedness initiatives, there is no technological solution able to replace an astute, perceptive healthcare provider. Throughout history, astute medical providers have been the sentinels of public health. Typically, they identify emerging problems for public health, rather than public health practitioners identifying the problems in advance for providers (Thacker, 1994). This notion was confirmed in 2001 when clinicians and laboratory professionals who had recently received preparedness training, diagnosed the index case of inhalational anthrax (Bush et al., 2001). The consequences of missing a sentinel case diagnosis were evident in 2014 when the first Ebola patient ever diagnosed in North America was missed on an initial visit to a Dallas, Texas, hospital emergency department. As a result, the patient returned days later much sicker and, before succumbing to his illness, infected two nurses providing his care.

The preparedness education and training of healthcare providers will continue to be the most important investments to mitigate the impact of a bioterrorism attack through rapid case identification. The intuition and skill of healthcare providers must be consistently challenged and sharpened so they are able to recognize a bioterrorism attack early and take the appropriate actions.

Disease Surveillance

Disease surveillance is an essential and familiar function of local and state public health agencies. Regular disease surveillance includes mandatory disease reporting by local healthcare providers, data entry and analysis by local or regional public health agencies, and additional analysis, reporting, and allocation of needed resources by state and federal public health agencies. However, the bioterrorism agents of concern have short incubation

periods, requiring rapid identification to facilitate early treatment to reduce morbidity and mortality. Most disease surveillance activities process and analyze information over time and are based on a confirmed diagnosis. They often lack the sensitivity needed to detect small changes in population health and are not specific enough to distinguish normal fluctuations in illness from unusual or suspicious cases. An ideal system includes a network of systems able to simultaneously analyze multiple variables, effectively comparing changes and trends and controlling confounders and background "noise" (Pavlin et al., 2002). The realization of a complete, integrated, effective, uniform system is many years away for most nations. In the United States, the largest system in development is BioSense. BioSense has a growing list of data sources including state and regional epidemiological surveillance systems, healthcare facilities, national laboratories, Veterans Affairs hospitals, Department of Defense, and others. It is the hope of Centers for Disease Control and Prevention officials coordinating the development of BioSense that trends in a sufficient number of healthcare and public health data sets will be capable of detecting growing epidemics before current reporting systems are able to detect subtle clues.

Active surveillance for special events is currently the most exhaustive and effective epidemiological surveillance available. This comprehensive, syndromic surveillance is accomplished at the Olympic Games, the Superbowl, political conventions, and other high-visibility events. This is a labor-intensive and expensive endeavor requiring additional staff placement in key points of healthcare delivery to gather information. The information collected includes respiratory, neurological, and dermatological symptoms that may indicate an outbreak or intentional biological release has occurred. Other active surveillance approaches include monitoring available information in public health and healthcare databases. These data may include ambulance runs, chief complaints of 911 calls, hospital admissions, school or work absenteeism, or trends in pharmaceutical or laboratory demands. The challenge of syndromic, integrated surveillance is twofold. First, the correct baseline must be determined over time and may fluctuate by season and other non-health-related variables. Signals depend on the accurate determination of triggers or thresholds. Many of these systems, therefore, have significant background "noise." In-depth analysis of what appears to be signals must be performed to properly create alarms. Trained epidemiologists are necessary to continuously evaluate the data produced.

The trigger for activating a bioterrorism response is difficult to define. Bioterrorism encompasses such a wide array of pathogens and pathogenic byproducts that it is impossible to define a "typical" bioterrorism event and establish appropriate triggers for response. In 1984, Dalles, Oregon, experienced a large outbreak of *Salmonella* gastroenteritis. More than 700 people became ill after eating at 10 local salad bars. The epidemiological investigation could not identify a single food as the source of the illnesses. Months later, the criminal investigation identified the origin of the outbreak as intentional contamination of area salad bars by members of a religious cult (Torok et al., 1997). In this case, the agent used was not lethal and initially appeared as a large, but accidental, foodborne outbreak. A bioterrorism scenario will unfold in a very different way if a lethal agent is used. If the agent is transmissible from person to person or if it is delivered by spraying an aerosol, the

"footprint" or focused area of an outbreak could expand across large regions. Clues that should raise healthcare provider suspicions include anything out of the ordinary. Every community has trends in seasonal illnesses with some variation from year to year. There may be obvious differences emerging, such as out-of-season "flu-like" outbreaks or more severe cases among groups who normally do not experience serious illness. An illness may be uncharacteristic for a particular region such as plague in New Jersey, or the strain may be unusual or resistant to treatment. Clues raising suspicion may range from more subtle trends to the obvious clues provided through claims made by aggressors or evidence identified by law enforcement authorities. Maintaining a high index of suspicion increases the likelihood of discovering an event sooner, and the swift discovery of an attack translates into more lives saved. Examples of the epidemiological clues that may suggest an act of bioterrorism are listed next:

Bioterrorism Epidemiological Clues

1. A large epidemic, with greater case loads than expected, especially in a discrete population
2. More severe disease than expected for a given pathogen, as well as unusual routes of exposure
3. Unusual disease for a given geographical area, found outside the normal transmission season, or impossible to transmit naturally in the absence of the normal vector for transmission
4. Multiple, simultaneous epidemics of different diseases
5. A zoonotic disease outbreak as well as a human outbreak, as many of the potential threat agents are pathogenic to animals
6. Unusual strains or variants, antimicrobial resistance patterns disparate from those circulating
7. Higher attack rates in those exposed in certain areas, such as inside a building if the agent was released indoors, or lower rates in those inside a sealed building if an aerosol was released outdoors
8. Intelligence that an adversary has access to a particular agent or agents
9. Claims by a terrorist of the release of a biological agent
10. Direct evidence of the release of an agent, with findings of equipment, munitions, or tampering

Julie A. Pavlin, Walter Reed Army Institute of Research, Washington, DC (Pavlin, 1999).

Environmental Monitoring

Other forms of surveillance include environmental monitoring and standoff detection. Detector research and development continue to advance. Biological monitoring includes a range of technologies from basic bioaerosol collectors to advanced laser

particle analyzers. There are a variety of point source detection technologies in development, including nucleic acid, antibody, whole cell, and mass spectrometry analysis technologies. These detectors may enhance preparedness for specific high-risk events or buildings but they will always have limitations. The greatest limitation in the foreseeable future is cost. Emerging detection technology is too expensive for most local government agencies. These detectors are not sensitive enough to detect the full range of biological threats at a low level or specific enough to distinguish between normal background biological material in the air and the pathogens of greatest concern. The equipment must also be prepositioned in areas most likely to experience an attack. This requires comprehensive and accurate risk assessments of each community. Once a risk assessment is accomplished, it must be continually monitored and updated according to community activities, events, and changes. Devices include portable detectors that may be used for special events and more stationary detectors such as the BioWatch system. BioWatch is a surveillance program in dozens of major US cities where discreetly placed air samplers continually draw air through a filter that is collected daily and tested for DNA associated with biothreat agents. Although this is an important tool, it cannot be successful without, and can never replace, well-trained healthcare providers, public health professionals, and surveillance systems.

Immediate Actions

Once a biological threat has been detected, the biothreat agent and population at risk must be quickly identified. Because most severe illnesses resulting from an act of bioterrorism will have an incubation period, there is a window of opportunity for postexposure prophylactic treatment. This is true for even the most lethal agents. Decisions must be made rapidly and the response needs to begin immediately. Communication must be quickly established with the population at risk. If there are specific measures to be taken to reduce individual risks, they must be shared. For example, if pneumonic plague is the disease of concern, those at risk may be advised to isolate themselves from family members to avoid the risk of spreading the illness. At the same time, hospitals will be preparing for patient surges, whereas public health officials may be setting up points of dispensing or coordinating other strategies for mass prophylaxis. Each response will be unique according to the agent, method of release, population at risk, environmental conditions, etc. However, the most basic preparedness measures still apply. Individuals and families need a communication plan in case difficulties arise in the local communication infrastructure due to the crisis. Everyone should maintain a home preparedness kit in case an elective or mandatory quarantine is put in place to limit the spread of disease. Most importantly, everyone at risk must stay informed and follow the instructions provided by officials.

Just as the public is being informed of the appropriate protective measures, those working in healthcare, public health, and the first response community must be provided with detailed response instructions. For example, infection control recommendations and requirements will need to be shared (see Table 6-2). If standard precautions are suggested,

Table 6-2 Sample Patient Management Guidelines for Bioterrorism-Related Illnesses

IMPORTANT PHONE NUMBERS: Infectious Diseases _____-_____ Infection Control _____-_____ Emergency Department _____-_____ Local Health Department _____-_____ State Health Department _____-_____	BACTERIAL AGENTS	Anthrax	Brucellosis	Bubonic Plague	Pneumonic Plague	Tularemia	Q Fever	VIRUSES	Smallpox	Venez. Equine Encephalitis	Viral Encephalitis	Viral Hemorrhagic Fever	BIOLOGICAL TOXINS	Botulism	Staph. Enterotoxin B
Isolation Precautions															
Standard Precautions for all aspects of patient care		X	X	X	X	X	X		X	X	X	X		X	X
Contact Precautions (gown & gloves; wash hands after each patient. encounter)				X*					X			X			
Airborne Precautions (negative pressure room & PAPR or N95 masks for all individuals entering the room)									X			X**			
Droplet Precautions (surgical mask)					X							X**			
Patient Placement															
No restrictions		X	X			X	X			X	X			X	X
Cohort "like" patients when private room unavailable				X	X				X			X			
Private room				X*	X				X			X			
Negative pressure									X			X**			
Door closed at all times									X			X**			
Patient Transport															
No restrictions		X	X	X		X	X			X	X			X	X
Limit movement to essential medical purposes only				X*	X				X			X			
Place mask on patient to minimize dispersal of droplets					X				X			X**			
Cleaning and Disinfection															
Routine cleaning of room with hospital approved disinfectant		X	X	X	X	X	X		X	X	X			X	X
Disinfect surfaces with 10% bleach solution or phenolic disinfectant												X			
Dedicated equipment (disinfect prior to leaving room)				X*					X			X			
Linen management as with all other patients		X	X	X	X	X	X			X	X			X	X
Linens autoclaved before laundering in hot water with bleach added									X						
Discontinuation of Isolation															
48 hrs of appropriate antibiotic and clinical improvement					X										
Until all scabs separate									X						
Duration of illness				X*								X			

STANDARD PRECAUTIONS - Standard Precautions prevent direct contact with all body fluids (including blood), secretions, excretions, non-intact skin (including rashes), and mucous membranes. Standard Precautions routinely practiced by healthcare providers include: splash/spray, and gowns to protect skin and clothing during procedures

*Contact precautions needed only if the patient has skin involvement (bubonic plague: draining bubo)
** Recommended When Caring for a Patient with Confirmed Ebola or Unstable Persons under Investigation (PUIs)
NOTE; REVIEW MOST CURRENT CENTERS FOR DISEASE CONTROL AND PREVENTION (CDC) RECOMMENDED INFECTION CONTROL PRACTICES FOR UPDATES
Adapted from guidance developed at Walter Reed Army Medical Center

this will include isolating blood and all other body fluids, secretions, nonintact skin, and mucous membranes of those who may be infected. Gloves and gowns must be used to prevent exposure to blood and other potentially infectious fluids. Mask and eye protection or a face shield must also be used if there are activities likely to generate splashes or sprays of blood, body fluids, secretions, or excretions. Appropriate hand washing is always necessary. Other precautions may include:

- Droplet Precautions: Provide private patient rooms or cohort patients with the same infectious agent. Use a mask if within 3 ft of the patient.
- Contact Precautions: Provide private patient rooms or cohort patients with the same infectious agent. Use gloves when entering the room and a gown if clothing is likely to have contact with an infectious patient, or contaminated surfaces or equipment.
- Airborne Precautions: Requires a negative pressure isolation room and appropriate respiratory protection such as the N95 respirator, which must be fit-tested.

Recovery

Following any bioterrorism event, there are likely to be strong debates over the need for decontamination and clean-up. With the notable exception of anthrax, clean-up will not be difficult for most pathogenic organisms. To ensure an effective cleaning agent is used, the Environmental Protection Agency (EPA) has established a listing of "antimicrobial products" under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). In the context of an environmental clean-up, antimicrobials are substances with chemical or physical properties that destroy or repress the growth of pathogenic organisms. Thousands of products are registered with the EPA for various applications. Over half of the products registered are specifically for controlling harmful organisms in healthcare settings. These antimicrobial products fall into two broad categories: those that disinfect, sanitize, or limit the growth of organisms and those that protect various objects and surfaces from contamination. There is a regulatory distinction between products used directly on food, those used on or in a living human body, and those products used to control microbes in the environment. The US Food and Drug Administration regulates those used directly on food or people. The EPA regulates the substances used for microbial control in the environment. The EPA has the final word on which antimicrobials will be used under different circumstances on different surfaces.

Mental and behavioral health recovery may be extensive, especially if the response has been prolonged and the case-fatality rates have been high. People who have been ill may be stigmatized. Critical family members may be permanently disabled or may have died. Economic recovery may be slow if people are afraid to re-congregate in workplaces and schools. Physical infrastructure may have been damaged or made non-usable by contamination or civil unrest. Health and medical resources may have been depleted or diverted

to the event creating new scarcity. These recovery issues need to be planned for, not only by government agencies but also by communities and individuals. Many of the ideas discussed in chapter Community Disaster Resilience, address possible solutions.

Summary

Bioterrorism is a particularly challenging public health preparedness issue. It requires a robust public health infrastructure to detect and manage an incident, a healthcare system with astute providers and well managed surge capacity, and a variety of disciplines prepared to follow and enforce public health recommendations. Bioterrorism preparedness requires hard work and a solid infrastructure consisting of a system of systems. These preparedness systems all have weaknesses and the only way to identify and solve those flaws is to provide thorough training and conduct regular multiagency exercises of local plans. Uniquely, a bioterrorism event response will require the partnership of public health with law enforcement. The list of potential pathogens that could be used by terrorists is long. Recovery will be complex because of the emotional and psychological impacts of terrorism. Although there will be unique aspects to any scenario, the establishment of a solid infrastructure that is well practiced in some of the more challenging response scenarios will provide the foundation for what is needed.

Websites

American Society for Microbiology. http://www.asm.org/.

Association for Professionals in Infection Control and Epidemiology. www.apic.org.

Association of Public Health Laboratories, Emergency Preparedness and Response. http://www.aphl.org/aphlprograms/preparedness-and-response/Pages/default.aspx.

Center for Health Security, University of Pittsburgh Medical Center. http://www.upmchealthsecurity.org/.

Center for Infectious Disease Research and Policy, University of Minnesota. http://www.cidrap.umn.edu/.

Centers for Disease Control and Prevention, Emergency Preparedness and Response Program, Bioterrorism. www.bt.cdc.gov/bioterrorism.

Food and Drug Administration, Bioterrorism and Drug Preparedness. http://www.fda.gov/drugs/emergencypreparedness/BioterrorismandDrugpreparedness/default.htm.

Infectious Diseases Society of America, Bioterrorism Resource Page. http://www.idsociety.org/Bioterrorism_Agents/.

Institute for BioSecurity, Saint Louis University. www.bioterrorism.slu.edu.

Journal of Bioterrorism & Biodefense, Journal of Bioterrorism & Biodefense. http://www.omicsonline.org/bioterrorism-biodefense.php.

National Library of Medicine, MedlinePlus, Biodefense and Bioterrorism. http://www.nlm.nih.gov/medlineplus/biodefenseandbioterrorism.html.

National Institute for Occupational Safety and Health, Guidance for Filtration and Air-cleaning Systems to Protect Building Environments from Airborne Chemical, Biological, or Radiological Attacks. http://www.cdc.gov/niosh/docs/2003-136/pdfs/2003-136.pdf.

New England Journal of Medicine, Clinical Management of Potential Bioterrorism-related Conditions. http://www.nejm.org/doi/full/10.1056/NEJMra1409755.

Occupational Safety & Health Administration, Bioterrorism. https://www.osha.gov/SLTC/bioterrorism/.

U.S. Army Medical Research Institute of Infectious Diseases. www.usamriid.army.mil/.

U.S. Department of Homeland Security, Ready.gov, Biological Threats. http://www.ready.gov/biological-threats.

References

Arnon, S.S., Schechter, R., Inglesby, T.V., et al., 2001. Botulinum toxin as a biological weapon: medical and public health management. JAMA 285, 1059–1070.

Arnon, S.S., Schechter, R., Maslanka, S.E., Jewell, N.P., Hatheway, C.L., 2006. Human botulism immune globulin for the treatment of infant botulism. N. Engl. J. Med. 354, 462–471.

Association of State and Territorial Health Officials (ASTHO), 2008. States of Preparedness: Health Agency Progress, second ed. Association of State and Territorial Health Officials, Washington, DC.

BBC News, July 29, 2015. Breaking Bad Fan Guilty of Dark Web Ricin Plot. BBC News. Available at: http://www.bbc.com/news/uk-england-33708611.

Becker, E., Toner, R., October 21, 2001. A Nation Challenged: The Victims; Postal Workers' Illness Set off No Alarms. The New York Times. http://query.nytimes.com/gst/fullpage.html?res=9C0DEED71431F937A15753C1A9679C8B63.

Bibel, D.J., Chen, T.H., 1976. Diagnosis of plague: an analysis of the Yersin-Kitasato controversy. Bacteriol. Rev. 40, 633–651.

Blinder, A., November 14, 2014. Two in Ricin Terrorism Plot are Each Sentenced to 10 years in Prison. The New York Times. Available at: http://www.nytimes.com/2014/11/15/us/ricin-terrorism-plot-sentencing.html?_r=0.

Borio, L., Inglesby, T., Peters, C.J., et al., 2002. Hemorrhagic fever viruses as biological weapons: medical and public health management. JAMA 287, 2391–2405.

Bush, L.M., Abrams, B.H., Beall, A., et al., 2001. Index case of fatal inhalational anthrax due to bioterrorism in the United States. N. Engl. J. Med. 345, 1607–1610.

Centers for Disease Control and Prevention (CDC), 1997. Fatal human plague—Arizona and Colorado, 1996. Morb. Mortal. Wkly. Rep. 46, 617–620. www.cdc.gov/mmwr/preview/mmwrhtml/00048352.htm.

Centers for Disease Control and Prevention (CDC), 1998. Botulism in the United States 1899–1996: Handbook for Epidemiologists, Clinicians, and Laboratory Workers. CDC, Atlanta, GA. http://www.cdc.gov/ncidod/dbmd/diseaseinfo/files/botulism.pdf.

Centers for Disease Control and Prevention (CDC), 2001. Considerations for distinguishing influenza-like illness from -inhalational anthrax. MMWR. 50 (44), 985–987. www.cdc.gov/mmwR/PDF/wk/mm5044.pdf.

Centers for Disease Control and Prevention (CDC), 2002a. Forensic Epidemiology: Joint Training for Law Enforcement and Public Health Officials on Investigative Responses to Bioterrorism. http://www.cdc.gov/phlp/docs/forensic_epidemiology/coursemgrguide.pdf.

Centers for Disease Control and Prevention (CDC), 2002b. Notice to readers: use of anthrax vaccine in response to terrorism: supplemental recommendations of the Advisory Committee on Immunization Practices. MMWR. 51 (45), 1024–1026. www.cdc.gov/mmwr/preview/mmwrhtml/mm5145a4.htm.

Centers for Disease Control and Prevention (CDC), 2007. Bioterrorism Overview. Available at: http://emergency.cdc.gov/bioterrorism/overview.asp.

Centers for Disease Control and Prevention (CDC), 2009. Plague. Available at: http://www.cdc.gov/plague/.

CNN.com, November 8, 2001. Postal Worker Suspected He Had Anthrax. http://archives.cnn.com/2001/HEALTH/conditions/11/07/911.anthrax/index.html.

Cunha, B.A., 2000. Tickborne Infectious Diseases: Diagnosis and Management. Marcel Dekker, New York, NY.

Dennis, D.T., 1998. Tularemia. In: Wallace, R.B. (Ed.), Maxcy-rosenau Last Public Health and Preventive Medicine, 14th ed. Appleton & Lange, Stamford, Conn, pp. 354–357.

Dennis, D.T., Inglesby, T.V., Henderson, D.A., et al., 2001. Tularemia as a biological weapon: medical and public health management. JAMA 285, 2763–2773.

Dixon, C.W., 1962. Smallpox. J & A Churchill Ltd, London, p. 1460.

Eitzen, E.M., Takafuji, E.T., 1997. Historical overview of biological warfare. In: Sidell, F.R., Takafuji, E.T., Franz, D.R. (Eds.), Medical Aspects of Chemical and Biological Warfare, Office of the Surgeon General, Borden Institute, Walter Reed Army Medical Center, Washington, DC, pp. 415–423. Available at: http://www.bordeninstitute.army.mil/cwbw/default_index.htm.

Emergent Biosolutions, January 31, 2002. Anthrax Vaccine-adsorbed (BIOTHRAX™). Manufacturer's prescribing information. www.bioport.com/pdf/emergent_biothrax_us.pdf.

Evans, M.E., Gregory, D.W., Schaffner, W., McGee, Z.A., 1985. Tularemia: a 30-year experience with 88 cases. Med. Baltim. 64, 251–269.

Fenner, F., Henderson, D.A., Arita, I., et al., 1988. Smallpox and its Eradication. World Health Organization, Geneva, Switzerland, pp. 1–276. http://apps.who.int/iris/handle/10665/39485.

Fidler, D.P., 2002. Bioterrorism, Public Health, and International Law. Faculty Publications. Paper 427 http://www.repository.law.indiana.edu/facpub/427/.

Food and Drug Administration (FDA), 2013. Questions about Smallpox and ACAM2000. Available at: http://www.fda.gov/biologicsbloodvaccines/vaccines/questionsaboutvaccines/ucm078041.htm.

Frischknecht, F., 2008. The history of biological warfare. In: Richardt, A., Blum, M.-M. (Eds.), Decontamination of Warfare Agents: Enzymatic Methods for the Removal of B/C Weapons. Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany. http://dx.doi.org/10.1002/9783527621620.ch1.

Gill, D.M., 1982. Bacterial toxins: a table of lethal amounts. Microbiol. Rev. 46, 86–94.

Henderson, D.A., Inglesby, T.V., Bartlett, J.G., et al., 1999. Smallpox as a biological weapon: medical and public health management. JAMA 281, 1735–1745.

Hendricks, K.A., Wright, M.E., Shadomy, S.V., Bradley, J.S., Morrow, M.G., Pavia, A.T., et al., February 2014. Centers for Disease Control and Prevention expert panel meetings on prevention and treatment of anthrax in adults. Emerg. Infect. Dis. [Internet]. http://dx.doi.org/10.3201/eid2002.130687.

Huggins, J.W., Bray, M., Smee, D.F., et al., 2001. Potential antiviral therapeutics for smallpox, monkeypox, and other orthopox virus infections. In: Presented at the WHO Advisory Committee on Variola Virus Research, -December 3–6, Geneva, Switzerland.

Inglesby, T., Dennis, D., Henderson, D., et al., 2000. Plague as a biological weapon: medical and public health management. JAMA 283, 2281–2290.

Inglesby, T., O'Toole, T., Henderson, D., et al., 2002. Anthrax as a biological weapon, 2002: updated recommendations for management. JAMA 287, 2236–2252.

Jernigan, J.A., Stephens, D.S., Ashford, D.A., et al., 2001. Bioterrorism-related inhalational anthrax: the first 10 cases reported in the United States. Emerg. Infect. Dis. 7, 933–944. http://wwwnc.cdc.gov/eid/article/7/6/01-0604_article.

Johnson, E., Jaax, N., White, J., et al., 1995. Lethal experimental infections of rhesus monkeys by aerosolized Ebola virus. Int. J. Exp. Pathol. 76 (4), 227–236.

Kolavic, S.A., Kimura, A., Simons, S.L., Slutsker, L., Barth, S., Haley, C.E., August 6, 1997. An outbreak of *Shigella dysenteriae* type 2 among laboratory workers due to intentional food contamination. JAMA 278 (5), 396–398.

Lew, D., 1995. Bacillus anthracis. In: Mandell, G.L., Bennett, J.E., Dolin, R. (Eds.), Principles and Practice of Infectious Disease. Churchill Livingstone Inc, New York, NY, pp. 1885–1889.

Lichtblau, E., Wade, N., August 18, 2008. F.B.I. Details Anthrax Case, but Doubts Remain. The New York Times. www.nytimes.com/2008/08/19/us/19anthrax.html#.

Mina, B., Dym, J.P., Kuepper, F., et al., 2002. Fatal inhalational anthrax with unknown source of exposure in a 61-year-old woman in New York City. JAMA 287, 858–862.

Morris, T., November 19, 2001. Tom Morris' Last Call. TIME. www.time.com/time/magazine/article/0,9171,1001251,00.html.

Muyembe-Tamfum, J.J., Kipasa, M., Kiyungu, C., Colebunders, R., 1999. Ebola outbreak in Kikwit, Democratic Republic of the Congo: discovery and control measures. J. Infect. Dis. 179 (Suppl. 1), S259–S262.

NC Institute of Medicine (NCIOM), 2007. Stockpiling Solutions: North Carolina's Ethical Guidelines for an Influenza Pandemic. http://www.nciom.org/publications/?pandemicfluplanning.

Oyston, P.C.F., Quarry, J.E., 2005. Tularemia vaccine: past, present and future. Antonie Leeuwenhoek 87, 277–281.

Palmer, C., June 17, 2015. Montco Man Gets 20 to 40 years for Ricin-laced Card. Philly.com. Available at: http://articles.philly.com/2015-06-17/news/63488347_1_nicholas-helman-birthday-card-plot.

Pavlin, J.A., 1999. Epidemiology of bioterrorism. Emerg. Infec. Dis. 5, 528–530.

Pavlin, J.A., Kelley, P., Mostashari, F., et al., 2002. Innovative surveillance methods for monitoring dangerous pathogens. In: Knobler, S.L., Mahmoud, A.F., Pray, L.A. (Eds.), Biological Threats and Terrorism: Assessing the Science and Response Capabilities. National Academy Press, Washington, DC, pp. 185–191.

Perry, N., January 7, 2009. 11 gay Bars Get Letters Threatening Ricin Attacks. The Seattle Times. Available at: http://www.seattletimes.com/seattle-news/11-gay-bars-get-letters-threatening-ricin-attacks/.

Rotz, L.D., Khan, A.S., Lillibridge, S.R., 2002. Public health assessment of potential biological terrorism agents. Emerg. Infec Dis. 8, 225–230.

Saslaw, S., Eigelsbach, H.T., Prior, J.A., et al., 1961. Tularemia vaccine study. I. Intracutaneous challenge. Arch. Intern. Med. 107, 121–133.

Shapiro, R.L., Hatheway, C., Swerdlow, D.L., 1998. Botulism in the United States: a clinical and epidemiologic review. Ann. Intern. Med. 129 (3), 221–228.

Shepard, C.W., Soriano-Gabarro, M., Zell, E.R., et al., 2002. Antimicrobial post exposure prophylaxis for anthrax: adverse events and adherence. Emerg. Infect. Dis. 8, 1124–1132. http://wwwnc.cdc.gov/eid/article/8/10/02-0349_article.

St. Louis, M.E., Peck, S.H., Bowering, D., et al., 1988. Botulism from chopped garlic: delayed recognition of a major outbreak. Ann. Intern. Med. 108, 363–368.

Stephenson, E.H., Larson, E.W., Dominik, J.W., 1984. Effect of environmental factors on aerosol-induced Lassa virus infection. J. Med. Virol. 14, 295–303.

Tackett, C.O., Shandera, W.X., Mann, J.M., et al., 1984. Equine antitoxin use and other factors that predict outcome in type A foodborne botulism. Am. J. Med. 76, 794–798.

Thacker, S.B., 1994. Historical development. In: Teutsch, S.M., Churchill, R.E. (Eds.), Principles and Practice of Public Health Surveillance. Oxford University Press, New York, NY, pp. 8–9.

Torok, T.J., Tauxe, R.V., Wise, R.P., et al., 1997. A large community outbreak of salmonellosis caused by intentional contamination of restaurant salad bars. JAMA 278, 389–395.

U.S. Congress (USC), June 12, 2002. Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Public Law, pp. 107–188. Available at: http://www.gpo.gov/fdsys/pkg/PLAW-107publ188/pdf/PLAW-107publ188.pdf.

U.S. General Accounting Office (USGAO), 2008. Combating Bioterrorism: Actions Needed to Improve Security at Plum Island-animal Disease Center. www.gao.gov/atext/d03847.txt.

Wehrle, P.F., Posch, J., Richter, K.H., et al., 1970. An airborne outbreak of smallpox in a German hospital and its significance with respect to other recent outbreaks in Europe. Bull. World Health Organ 43, 669–679.

Weiss, R., Snyder, D., 2002. 2nd Leak of Anthrax Found at Army Lab. Washington Post. Retrieved April 24, 2002. B1.

Williams, P., July 16, 2014. Woman Who Mailed Ricin Letters to Obama Sentenced to 18 years. NBC News. Available at: http://www.nbcnews.com/news/us-news/woman-who-mailed-ricin-letters-obama-sentenced-18-years-n157531.

Williamson, E., May 27, 2003. Ft. Detrick Unearths Hazardous Surprises. Washington Post, p. B1.

7

Bombings and Explosions

OBJECTIVES

- Describe recent trends in bombings around the world.
- List the various categories of blast injuries.
- Recognize the types of conditions considered to be primary blast injuries.
- Distinguish the differences between secondary and tertiary injuries.
- Provide examples of quaternary blast injuries.
- Define types of barotrauma injuries.
- Summarize healthcare facility lessons from the 1995 Oklahoma City Bombing.
- Explain the difference between preparedness measures for terrorist bombings and those for industrial explosions.
- List three things that reduce the morbidity and mortality impact of a car bomb.
- Describe how a bomb threat may be recognized and the appropriate response to it.
- List several important factors and key differences in triaging explosion victims.

Introduction: 2005 London Terrorist Bombings

Anat was born and raised in Israel. After attending high school in Jerusalem and completing her service obligation with the Israeli Army, she studied modern dance. This grew into a passion for the arts which led her to move to London, where she immersed herself in the arts community and worked as an administrator with a children's charity. She was a petite 39-year-old, whom her friends described as intelligent, warm, and witty. According to her boyfriend, Anat was hoping to return to Israel to visit her parents, but was afraid to return because of the increasing number of suicide bombing attacks. In a tragic ironic twist, Anat's life was cut short by a suicide bomber on the streets of London near a popular statue of Ghandi in Tavistock Square (see Fig. 7-1). Anat was on the Number 30 bus talking on the phone with her boyfriend when a suicide bomber detonated a bomb in a backpack, killing 13 (BBC, 2005b). It was one of four suicide bomber attacks that day in London. Fifty-two people died in the four attacks, and 770 were injured (BBC, 2005a).

The frequency of terrorist attacks has risen sharply in recent years. Worldwide deaths due to terrorism rose from 11,133 in 2012 to 17,958 in 2013. The 2013 attacks were carried out in 87 different countries but 80% of the fatalities occurred in just 5: Iraq, Afghanistan, Pakistan, Nigeria, and Syria. Over 60% of all attacks involved the use of explosives (IEP, 2014). This terrorist tactic is fueled by the growing desire to maximize the number of fatalities. This has not always been the aim of terrorist bombers. For many years, the

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FIGURE 7-1 Ambulances at Russell Square, London, after the July 7 bombings. *Photo by Francis Tyers.*

Irish Republican Army (IRA) detonated bombs throughout the United Kingdom to draw attention to its cause. Its bombs were crude and not very effective. In fact, IRA terrorists sometimes accidentally detonated the bombs, killing themselves before they reached their objectives (Rose, 1990). Civilian casualties from IRA bombings were usually low, because their methods were low-tech and the primary objective was media attention and the public and political pressure the attacks generated. However, today's bombers often want to produce as many civilian casualties as possible, and these terrorists are acquiring the technologies and methods to reach this objective. As the materials and directions for bomb-making continue to proliferate, the likelihood of future bombing incidents will continue to increase, including the possibility of suicide bombings in nations without a history of such events. Recent history supports the suggestion that these types of attacks are becoming more likely (Frykberg, 2003). In fact, there was a fivefold increase in the total number of terrorist attacks from 2000 to 2013 (IEP, 2014).

Explosion threats exist beyond the battlefield and terrorist incidents. Civilian industrial accidents pose similar challenges for public health and medical preparedness and response. The threat of industrial accidents is widespread across several industrial sectors that have higher risk of explosions, including the oil and gas industry, agriculture, energy, and defense. This includes both production facilities and transportation routes. These threats are dynamic and change over time. For example, the recent expansion of the domestic oil and gas industry in the United States has seen more deaths from fires and explosions than in any other private industrial sector (Soraghan, 2014). Many of the most destructive industrial explosions in history involve ammunition accidents in the defense

FIGURE 7-2 A locomotive and debris after the 1947 Texas City disaster, April 16, 1947. *Photo courtesy of the Moore Memorial Public Library, Texas City, Texas.*

sector. The worst defense sector accident ever recorded was the explosion and sinking of a crowded Chinese vessel in 1948. It was carrying over 6000 passengers, including about 4000 Manchurian refugees, when a boiler explosion set off a large cargo load of ammunition. The death toll was estimated at about 6000 (Chicago Tribune (CT), 1948). The agriculture sector also has experienced a large number of explosions, ranging from small dust explosions in grain elevators to enormous ammonium nitrate explosions. The worst industrial disaster in US history began with an ammonium nitrate explosion on April 16, 1947. The *SS Grandcamp*, transporting about 2300 tons (over 4.6 million pounds, 2 million kilograms, or 2100 metric tons) of ammonium nitrate, detonated at the docks of the Texas City harbor (see Fig. 7-2). The initial explosion caused widespread damage and was followed by secondary explosions, including that of another ship carrying ammonium nitrate as well as several refineries. There has been ongoing debate concerning the exact number of fatalities, but it is estimated that nearly 600 individuals perished in the explosions (AE, 2009; NYT, 1947). An initial report described the scale of the explosion:

> *Damage to property outside the dock area was widespread. Approximately 1000 residences and business buildings suffered either major structural damage or were totally destroyed. Practically every window exposed to the blast in the corporate limits was broken. Several plate glass windows as far away as Galveston (10 miles) were shattered. Flying steel fragments and portions of the cargo were found 13,000 ft distant.*

> *A great number of balls of sisal twine, many afire, were blown over the area like torches. Numerous oil tanks were penetrated by flying steel or were crushed by the blast wave which followed the explosions. Drill stems 30 ft long, 6 3/8 inches in diameter, weight 2700 pounds, part of the cargo of the S. S. GRANDCAMP were found buried 6 ft in the clay soil a distance of 13,000 ft from the point of the explosion.*
>
> *FPEB (1947).*

Explosion Injury-Related Definitions

Barotraumas Damage resulting from a dramatic pressure change released from an explosion. These are injuries to air-filled organs such as the middle ear, sinuses, lungs, or digestive system.

Blast lung injury A major cause of morbidity and mortality among blast victims. The clinical diagnosis is characterized by respiratory difficulty and hypoxia. There are often no external chest injuries. The internal lung injuries include tearing, hemorrhage, contusion, and edema.

Gastrointestinal barotraumas Digestive system injuries resulting from the dramatic changes in barometric pressure projected from the point of a detonation.

High-order explosives (HEs) Explosive materials generating a supersonic shock wave. The overpressure moves thousands of yards (meters) per second. HE materials include PETN (pentaerythritol tetranitrate), RDX (cyclonite), TNT (trinitrotoluene), NG (nitroglycerin), Composition C4, Semtex, and ANFU (ammonium nitrate fuel oil).

Low-order explosives (LEs) Explosive materials generating a subsonic shock wave with no significant overpressure. LE materials include petroleum products (eg, Molotov cocktails) and black powder (eg, pipe bombs or pressure cooker bombs).

Otic barotrauma Middle ear injuries resulting from the dramatic changes in barometric pressure projected from the point of a detonation.

Primary blast injury Damage occurring to the "hollow" organs of the body from the rapid overpressure generated by a blast wave. The most susceptible areas include the ears, lungs, and abdomen.

Pulmonary barotraumas Lung injuries resulting from the dramatic changes in barometric pressure projected from the point of a detonation.

Quaternary blast injury Any other damage that falls outside the first three categories, including burns, subsequent respiratory problems from dust, or exposure to hazardous materials included in or released by the blast.

Secondary blast injury Damage resulting from the flying debris of an explosion, including primary bomb fragments and secondarily propelled debris. Injuries include penetrating and blunt traumas.

Sinus barotraumas Sinus injuries resulting from the dramatic changes in barometric pressure projected from the point of a detonation.

Tertiary blast injury Damage resulting from being thrown by the blast winds. These are primarily blunt trauma injuries, but can also include penetrating injuries if a victim is propelled against something sharp.

Human Health Effects

Blast injuries are typically grouped into four categories including primary, secondary, tertiary, and miscellaneous injuries (see Table 7-1). These broad categories have been established to aid in the understanding of the complex assortment of injuries associated with explosions and to provide structure for the triage process.

Table 7-1 Types of Blast Injuries

Blast Injury Type	Mechanism of Injury	Health Impact
Primary	Crushing overpressure from a blast wave (not blast wind) causing internal injuries	Damage to "hollow" organs such as the eyes, middle ears, lungs, and gastrointestinal tract
Secondary	Flying debris	Penetrating and blunt trauma injuries
Tertiary	Injuries resulting from being thrown by the wind	Fracture and blunt trauma
Quaternary	Any complicating factor not in the other three categories, including injuries, illnesses, and diseases	Burns, crush injuries, cardiovascular problems, and respiratory problems, including exacerbation of asthma or chronic obstructive pulmonary disease

Primary blast injuries result from the rapid overpressure or shock wave produced by an HE. These injuries result from the dramatic changes in barometric pressure projected from the point of a detonation (Benzinger, 1950). Severe damage to the air-filled organs of the body may result from this rapid pressure change, and these injuries are referred to as barotraumas. Air-filled organs that can experience damage include the middle ear (otic barotraumas), the sinuses (sinus barotraumas), the lungs (pulmonary barotraumas), and the digestive system (gastrointestinal barotraumas). The most sensitive and most frequently injured hollow organ is the eardrum or tympanic membrane. A change in atmospheric pressure of no more than 5 pounds per square inch (psi) or 35 kPa (kPa) can rupture the eardrum, whereas it usually requires nearly 10 times that amount (56–76 psi or 385–525 kPa) of overpressure to damage other hollow organs in the body. However, there have been cases of bomb victims experiencing lung damage even when their eardrums have remained intact (Katz et al., 1989). Depending on the overpressure generated by a blast, the injury can extend into the middle and inner ear, resulting in permanent hearing loss. The second most sensitive hollow organ is the lung. Blast damage to the lungs is the most common cause of life-threatening injury following an explosion (Leibovici et al., 1999). The change in pressure can cause lung contusions and rupture of alveolar capillaries, resulting in hemorrhage, pneumothorax (collapsed lung), hemothorax (internal bleeding in the chest), pneumomediastinum (air leaking from the lungs into the mediastinum), and subcutaneous emphysema (air leaking from the lungs under the skin of the chest) (Coppel, 1976; de Candole, 1967). The primary cause of death among the earliest primary blast fatalities is alveolar rupture with arterial air embolism (Phillips, 1986).

There is little to be done to protect against primary blast injuries. Even bomb technicians using the most advanced body armor cannot be protected from barotraumas during a blast. Although body armor can offer some protection against projectile injuries, it cannot prevent primary trauma resulting from overpressure (Mellor and Cooper, 1989). In addition to barotrauma injuries, the brain can experience a concussion or an acute air embolism (air bubbles in the blood) from sudden pressure changes. These injuries can

lead to central nervous system damage and traumatic brain injury requiring years of rehabilitation (Adler et al., 1983).

Secondary blast injuries consist of the penetrating wounds caused by fragments propelled by the explosion. For battlefield or terrorist explosions, there are two categories of fragments. Primary fragments are those built into a weapon. For example, suicide bombers often pack nails or ball bearings around explosive charges to increase the lethality of the explosion. Secondary fragments are the other debris generated by an explosion, such as flying glass. In most mass-casualty-generating explosions, secondary blast injuries are responsible for the majority of morbidity and mortality (Anderson and Feliciano, 1997). These fragments reach much farther and injure more people than the primary blast wave does. Explosion projectiles injuring those not killed but in close proximity to the blast can travel up to 1500 m per second or over 3355 mph (5400 kph) (see Fig. 7-3) (Bellamy and Zajtchuk, 1991; Phillips and Richmond, 1991).

In attacks on large buildings with many windows, flying glass is a major cause of injury and can be spread over a wide area. For example, the 1998 US Embassy bombing in Nairobi sent flying glass up to 2 km (over 1.2 miles) from the scene of the explosion, which injured people even at that distance (Wightman and Gladish, 2001). These types of injuries can

FIGURE 7-3 The moment of a blast. A Japanese bomb hitting the flight deck of the *USS Enterprise*, August 1942. This distinctive photo was taken by Robert Frederick Read, US Navy. Although the film in his camera was saved, he lost his life taking it. *Photo courtesy of the US National Archives.*

also be challenging for first responders to assess. A seemingly small wound may be an entry wound which is much more serious than it appears (Nixon and Stewart, 2004).

The term most commonly used to describe primary fragments from a weapon is "shrapnel." This name comes from the inventor of the fragmentation bomb. Henry Shrapnel was a British Army officer and inventor who created the fragmentation shell in the early 1800s.

Tertiary blast injuries are wounds sustained by individuals thrown by the blast winds (Bellamy and Zajtchuk, 1991; Coppel, 1976; de Candole, 1967). A variety of injuries can result from rapid acceleration and deceleration of the body, including fractures and blunt traumatic injuries. Depending on the size of the explosion, the blast wave is often capable of rolling a car or collapsing a building.

Quaternary blast injuries are all the remaining injuries observed among victims that are not due to primary, secondary, or tertiary injuries. These injuries further complicate the triage process for healthcare providers, with the introduction of patients with crush injuries syndrome and compartment syndrome. Quaternary injuries include burns, crush injuries, breathing problems from dust, smoke, or chemical releases, and any other injury not included in other categories.

An explosion is a complex process with many variables that influence morbidity and mortality. The type of delivery device used, amount and type of explosive material, distance from the explosion, barriers between the explosion and the victims, and whether the blast occurs indoors, outside, or in the water are just a few variables making the outcome of an explosion difficult to predict. The energy released rapidly dissipates in an open field, whereas an indoor explosion, or one in an urban setting, can be more destructive and accelerate down hallways or alleys. Although blast injury types are consistent, severity is dependent upon factors such as those listed above (Stein and Hirshberg, 1999; Brismar and Bergenwald, 1982; Frykberg et al., 1989; Hadden et al., 1978; Johnstone et al., 1993).

A fire occurred at a fertilizer storage facility in the town of West, Texas on April 17, 2013. As local volunteer firefighters fought the blaze, others quickly went door to door to homes, apartments, and a nursing home to warn the community of a potential explosion risk from the stored ammonium nitrate in the burning building. As those nearby were evacuating, a massive explosion occurred. The blast damaged nearly 300 of the 700 homes in the town. On the site of the storage facility, the blast created a crater about 100 ft wide and 10 ft deep. Twelve first responders fighting the fire, and two local residents, were killed by the blast. At least 252 individuals sustained direct injuries (WMCPHD, 2014). The local and state health departments partnered on an investigation reviewing numerous medical records and a variety of reports. The explosion injury patterns are displayed below in Fig. 7-4.

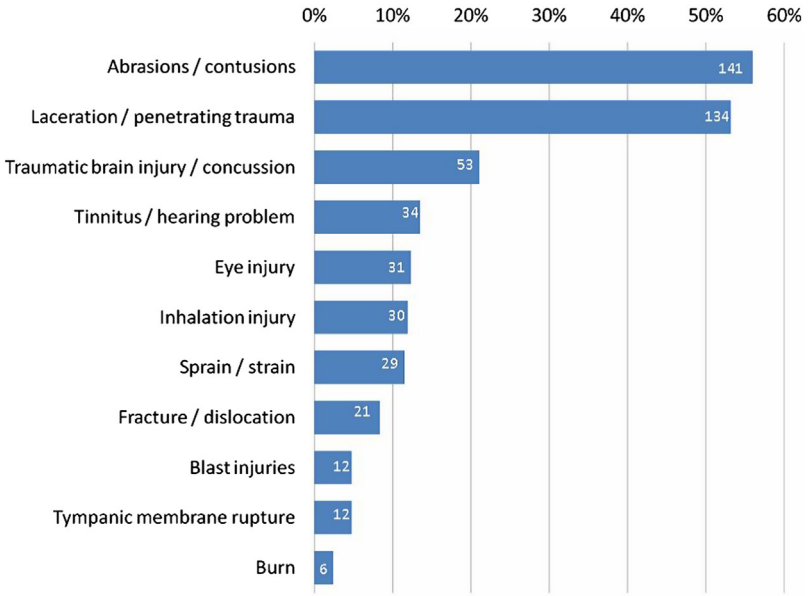


FIGURE 7-4 Injuries sustained by 252 directly injured patients resulting from the West, Texas fertilizer plant explosion (WMCPHD, 2014).

1995 Oklahoma City Bombing

It started off as a typical day in Oklahoma City as people filed into the Alfred P. Murrah Federal Building. Some were going to work. Others were dropping off children at day care, stopping by the Federal Employees Credit Union, or taking care of personal business in one of the many federal offices. Among those at the "Murrah Building" were Dr. Charles Hurlburt and his wife Jean. She was a nurse and he was a retired professor from the University of Oklahoma. Micky Maroney, a Secret Service agent and former defensive end for the 1964 national champion University of Arkansas Razorbacks was working in his office. From Tinker Air Force Base, Airman First Class Cartney McRaven had just dropped by the Social Security office to report her upcoming name change. She was getting married in four days. Playing with over a dozen little friends at the America's Kids Child Development Center on the second floor was little Baylee Almon, who had just celebrated her first birthday the day before (OCNMM, 2015).

The faces of those at the federal building that day were a tapestry of society with many ages, races, and faiths represented. In an instant, those mentioned above were gone. A truck bomb ripped away the front of the building claiming the lives of 167 people, including 19 children, and injuries with 83 people hospitalized and 509 treated as outpatients Mallonee et al., 1996. Shortly after the dust began to settle, a Pulitzer Prize winning photo was captured by loan specialist and amateur photographer Charles Porter. It was of Oklahoma City Fire Captain Chris Fields carrying the tiny broken body of Baylee Almon from the scene (Kurt, 2005). It was the first major terrorist attack on US soil and was perpetrated by antigovernment domestic terrorist Timothy McVeigh, who was put to death for the attack in the summer of 2001.

FIGURE 7-5 Construction workers erect an external elevator on the side of the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, after a bomb attack destroyed the building. *DoD photo by US Army Staff Sgt. Mark A. Moore.*

The Oklahoma City Bombing (Fig. 7-5) was the impetus for many hospital preparedness activities which have become the underpinnings of US healthcare system preparedness. The health and medical lessons learned form the basis for much of what is done in healthcare facilities across the nation to enhance preparedness for future disaster events. Perhaps the most concise summary of the lessons learned is from the Oklahoma Hospital Association's Sheryl McLain (McLain, 1995):

- Lesson One: Never underestimate the importance of having disaster preparedness plans in place which are practiced regularly via mock disaster drills.
- Lesson Two: No amount of planning or disaster drills could have thoroughly prepared us for the thunderous blast which shattered us—physically and emotionally—on April 19, 1995.
- Lesson Three: Our medical community was prepared to handle mass casualties. Immediately following the blast, thousands of medical and nonmedical volunteers

converged upon the downtown area. Within 3 minutes, seven staffed ambulances were in route to the scene; within 60 minutes, 66 ambulances were staffed and operational. A total of 47 ambulance services and 103 units were involved—many from outlying areas. More than 400 doctors and nurses rushed to the hospital located closest to the scene; therefore, there were two physicians caring for every 1 of the 202 patients taken there. Most of the medical response took place within the first 2 hours after the blast.

- Lesson Four: It is critical to involve phone companies in disaster-preparedness planning. Within the first 2 hours following the bombing, 12 million calls were attempted within the metropolitan area; the majority of the 1800 "911" (emergency) calls attempted during the first hour alone received busy signals. Our local phone company donated all resources to the rescue and recovery effort; 1500 phone lines were set up in and around the perimeter of the site. Long distance services were also donated so that rescue workers could call home. Wireless phone companies donated hundreds of phones and batteries. Three cells on wheels were brought in to add cellular capacity. One wireless phone company donated 1052 phones and contributed $4 million worth of equipment, time, and resources. When forming a community-wide disaster preparedness committee, do not overlook leaders from telephone or cellular companies.
- Lesson Five: It is imperative to frequently test communications systems, including backup systems. At approximately 10:30 am, all Oklahoma City hospital emergency rooms lost phone and radio contact with the local ambulance service. A backup radio system was in place in some but not all of the emergency rooms. Because of the bombing, each hospital's backup radio system was evaluated, and if necessary was upgraded or replaced. Daily roll calls now occur between the ambulance service's central dispatch office and each Oklahoma City hospital.
- Lesson Six: Building relationships with other disaster-response agencies will lessen the confusion during a disaster. With phone lines overloaded, communication between agencies was a tremendous problem. Most of the pleas for medical personnel, supplies, and other needs were disseminated by the news media to the masses, instead of agency to agency. Some of the needs were justified, but many were not. This resulted in a lot of confusion, poor distribution of medical personnel, and wasted supplies.
- Lesson Seven: It is important to have the ability to share basic patient information with and among hospitals as soon as possible after a community-wide disaster. Because victims were treated in 18 hospitals, a centralized tracking system would have been helpful to hospitals and to those traveling from hospital to hospital searching for their loved ones.
- Lesson Eight: Working with the international media for an extended length of time can be very challenging. Local media coverage at the bomb site and outside hospital emergency rooms began almost immediately. This live coverage continued nonstop—with no commercial interruptions—for 110 hours. However, the international media spotlight would shine on Oklahoma City for several weeks. Public relations staffing will be necessary 24 hours a day during the first several days following a disaster. Consider seeking help from outside volunteers, including experienced public relations

professionals from other hospitals or your hospital's system. A public relations/media room should be set up to accommodate a large number of people, cameras, and other media equipment. This area should be easily accessible to the main entrance of the hospital, but away from the emergency room and patient care areas. Clearly marked directions to the media room are a must, as is an alert security staff. Parking lot signs directing the media and family members to designated parking areas are an additional help. To avoid duplicating tiresome patient interviews, consider pool interviews. A separate room for interviews with family members should also be set up away from the patient's room. Do not forget the importance of your local news media when the national and international media come into your community. Make every effort to ensure local media representatives are treated as fairly and equitably as the national media. Decide in advance whether television tabloid or talk show hosts will be treated as equitably as "news" reporters.

- Lesson Nine: During a disaster, people need to do something to help. Because of the number of requests the Oklahoma Hospital Association received from healthcare workers across the United States, the "Hospitals Helping the Heartland" disaster relief fund was established as a means through which hospital workers *could* assist bombing victims in a meaningful way.
- Lesson 10: It takes a lot of resources and time for a community to heal emotionally. Ours was one of 14 provider groups to endorse the publication and distribution of an informational booklet designed to assist individuals with emotional healing following the disaster. A centralized mental health entity—Project Heartland—was established shortly after the bombing by the Oklahoma State Department of Mental Health, with initial funding from the Federal Emergency Management Association, and later by the Department of Justice. Its goal was to coordinate the provision of the bombing victims' diverse mental healthcare needs.

Of all the lessons we learned, the most important ones were those which reminded us of how fragile and precious life is, and the value of our loved ones; and those which showed the nation and the world that we are all much stronger when we are unified and work together toward a common goal.

Prevention and Preparedness

It is important for preparedness and emergency management professionals to fully assess potential bombing targets and industrial explosion risks across their respective jurisdictions. Vulnerable and high-risk facilities should be included in mitigation and preparedness planning to better protect the individuals in and around them. Security measures should be reviewed by qualified professionals. Training should be provided to high-risk facility occupants. This may include facilities that house financial, social, religious, and political organizations. In addition, military installations, transportation systems, dams, and petrochemical operations require additional explosion-threat-preparedness planning considerations.

As with any disaster health threat, morbidity and mortality outcomes can be improved through planning, training, and exercises (see Fig. 7-6). Planning for bombing or industrial explosion threats includes physical security and increasing awareness of facility occupants. Industrial explosion preparedness includes many similar measures, but begins in the early stages of the design process. For example, a method developed by the Dow Chemical Company for the chemical process industry, the Dow Fire and Explosion Index (FE&I), ranks the risks of explosions and fires using an analysis of processes and associated materials.

Although physical security planning may be complete for high-risk buildings, it may miss specific bomb threat considerations. Security planning needs to be regularly reviewed and updated with bombing scenarios in mind. A bomb incident plan provides a detailed description of the procedures to be followed when threats are detected. This includes raising building occupant awareness of threat identification and orienting them to appropriate individual response. Physical security and bomb incident plans are distinct but interdependent. Physical security measures can be bypassed if threats are not quickly recognized by those at risk. Once a threat is recognized, an appropriate response is essential to limiting potential morbidity and mortality, particularly due to secondary devices which can follow an initial bombing. The only way to ensure appropriate response is through coordinated planning, training, sustained awareness, and exercise. This holds true for critical facilities in which procedures are required to be in place for directing appropriate initial action, as well as for first responders and nearby healthcare facilities responsible for managing the public health and medical impact of an explosion. Adequate planning, training, and exercise can prevent avoidable injuries resulting from both bombing and industrial explosion threats.

FIGURE 7-6 Firefighters from the 375th Civil Engineer Squadron help carry victims out of harm's way during an exercise April 22, 2015, at Scott Air Force Base, Illinois. The exercise tested emergency response and helped prepare emergency personnel for real-world disasters. *DoD photo by US Air Force Senior Airman Tristin English.*

Physical Security

It is impossible to fully protect any facility from a determined attacker, particularly a suicide bomber. However, the impact of an attack can be vastly reduced through enhanced physical security. The first step in risk reduction is to seek out and eliminate locations where improvised explosive devices can be hidden. One common location is a trash receptacle near a building entrance. Trash cans near the road are popular places for roadside bombs in recent conflicts in Iraq, Afghanistan, and Syria. Other popular hiding places for bombs are vending machines, mailboxes, phone booths, and heavy underbrush or weeds. Any place a small package can be discreetly concealed should be considered a possible threat location when developing a physical security plan. Potential explosive device carriers such as cars and trucks should be kept at a safe distance. It is also important to limit parking spaces in close proximity to the building and/or increase security for parking located within or adjacent to the building. Establishing this distance between buildings and vehicle access moves the potential blast wave far enough away to take advantage of the exponential decrease in overpressure of a blast moving through open air (Fig. 7-7). If adequate distance cannot be established, barriers may be erected to deflect the blast wave away from a targeted facility. Solid walls of concrete, steel, and composite materials can be used. Other lower-tech solutions include barriers created by mounds of sand or dirt, or large containers of water. In addition, window laminates and treatments can reduce the likelihood of secondary blast injuries due to flying glass. Many nations have invested tremendous resources in "hardening" facilities using these materials, and work continues in developing advanced blast mitigation materials used as barriers or incorporated into the design of high-risk facilities (Fig. 7-8). Additional security measures include a procedure for inspecting incoming visitors and mail, effective key control, keeping exits passable,

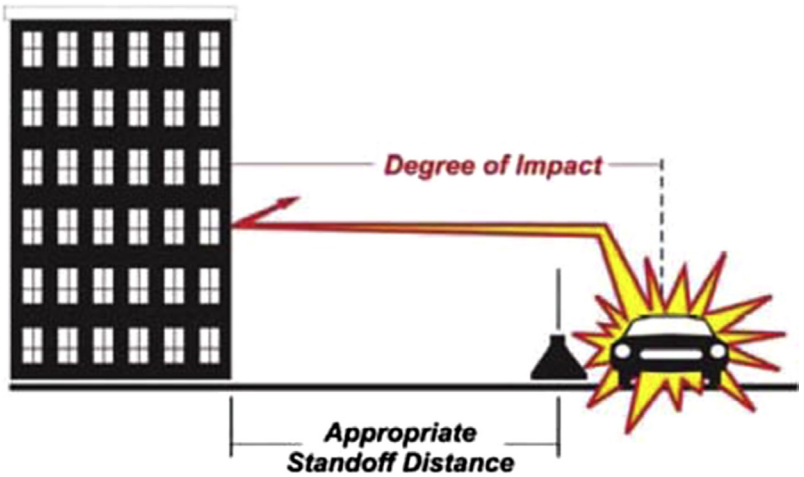


FIGURE 7-7 Stand-off distance is the safe distance from an unscreened individual or vehicle based on the maximum amount of explosive material that could realistically fit into a container or vehicle. *Illustration courtesy of the US Department of Transportation.*

FIGURE 7-8 A contractor installs a blast-resistant window frame in the outer facade of the Pentagon's E-ring. *Photo courtesy of the DoD Pentagon Renovation Program.*

and ensuring sufficient lighting inside, outside, and for emergencies. All security measures should be tested periodically to identify gaps and to improve effectiveness. Local law enforcement should be invited to review plans and to provide suggestions on ways to reduce vulnerability and increase response effectiveness.

Explosives Threat Detection and Identification

There has been a proliferation of new explosives-detection technology in recent years. The growing threat of terrorism has also raised the awareness of how to recognize a variety of related risks, including how to identify and report suspicious persons and packages. A threat can be detected in a variety of ways. In airports, X-ray machines are used to screen luggage, and bomb sniffing dogs are often used to identify explosive materials (Fig. 7-9). Some luggage and passengers are checked with trace explosives-detection devices as well. As the threat has increased, this technology has accelerated to include electronic nose technology capable of literally sniffing out explosives using an assortment of sensors which respond to different odors. Each odor has a complex fingerprint or "smell print"

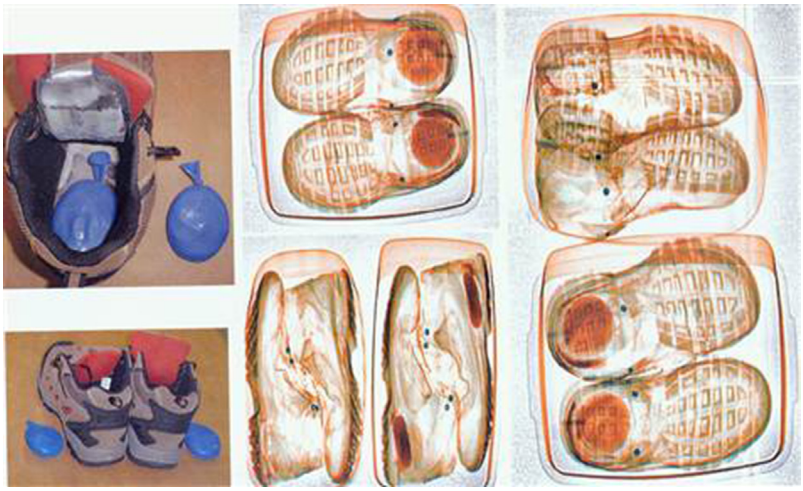


FIGURE 7-9 On left, images of shoes with hidden explosives. On right, the X-ray images of the shoes with explosives and without explosives. The dark spots on the X-rays indicate the explosives. *Photo courtesy of US Transportation Security Administration.*

that can be identified by this technology (Pearce et al., 2002). There are also new spray-on polymers which change color under ultraviolet light to detect specific types of explosive materials (Barras, 2008). Improvements continue to be made to almost all analytical explosive detection methods. These methods can identify explosives at lower detection limits faster and at greater distances (Moore, 2007). These accelerating innovations exhibit tremendous promise for future explosive risk identification.

Individual Awareness

Individual awareness of bomb threats is also essential. However, when training occupants of high-risk facilities in the recognition of threats, it is important that they understand their limitations. Individuals should be trained to recognize things that are out of place, but should leave the final determination of a threat up to trained responders. A threat assessment should be accomplished with the help of local law enforcement, which should also be involved in decisions regarding appropriate courses of action. Threats may be unannounced but may also be announced in writing or with a phone call. If a written threat is received, all materials including the envelope should be secured and turned over to law enforcement. Depending on the overall objective of a bomber, the threat may be received in a phone call, text, or email. Training should include orienting staff about what to do if a threatening call is received. This includes the following:

1. Attempt to keep the caller on the line as long as possible.
2. Get all the information possible.
3. Ask for details on the bomb's location and how it can be activated.
4. Remind the caller that innocent people could be hurt.

5. Listen for background noises like traffic or music which could indicate caller location.
6. Note caller's voice (male/female, accents, impediments).
7. Note caller's temperament (calm, angry, excited).
8. Ask the caller to repeat as much as possible.
9. Never hang up before the caller does.
10. Immediately contact law enforcement.

Recognizing Suspicious Packages

The use of a letter or a package to deliver an explosive device is a potential threat which should be well understood, especially by those handling incoming mail and deliveries. There are many clues that should raise suspicion and require action. If a letter or package is received with one or more of the conditions displayed in Fig. 7-10, procedures should be in place and quickly followed to isolate the delivery and report it to law enforcement. If parts of a delivery seem out of order with misspellings, a return address which does not match the postmark, restrictive markings such as "Confidential," "Personal," "Opened Only by Addressee," the package should not be handled and local authorities should be contacted immediately. All staff handling incoming mail should be trained in four simple steps regarding the handling of suspicious mail or packages. Staff should be reminded of these steps through regular staff messaging, training, posters, and other methods. These steps include:

1. Do not shake, bump or attempt further handling of the letter or package.
2. Isolate the letter or package and look for suspicious markings or conditions.
3. Do not touch or attempt to open the letter or package.
4. Clear the area and contact law enforcement officials.

FIGURE 7-10 Indicators of a suspicious package or letter. *Images courtesy of the US Federal Bureau of Investigation.*

Immediate Actions

If a threat necessitates an evacuation from a building, occupants should quickly collect personal items such as purses and briefcases so that these items are not among the possible threats needing to be assessed by bomb technicians. As with a building fire, elevators should not be used, and there should be a rallying point away from the building for a head count. If a specific threat has been identified, it is imperative that everyone at risk be evacuated immediately to a safe distance away from the threat. Refer to Table 7-2 for distances based upon the type and size of explosive threat. Everyone inside the "building evacuation distance" must evacuate immediately (both inside and outside buildings). Those who are outside the "building evacuation distance" but inside the "outdoor evacuation distance" should seek shelter immediately inside a building and away from windows and exterior walls. There should not be anyone allowed outside unless they are beyond the "outdoor evacuation distance (Quenonmoen et al., 1996)."

Table 7-2 Explosive Threat Evacuation Distances

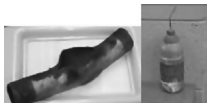
Explosive Threats		Explosives Capacity[a]. TNT Equivalent in Pounds and Kilograms	Building Evacuation Distance[b]	Outdoor Evacuation Distance[c]
	Pipe bomb	5 lbs 2.3 kg	70 ft 21 m	850 ft 0.16 miles 259 m 0.26 km
	Briefcase Suitcase Backpack	50 lbs 23 kg	150 ft 46 m	1850 ft 0.35 miles 564 m 0.56 km
	Compact sedan	500 lbs 227 kg	320 ft 0.06 miles 98 m	1500 ft 0.28 miles 457 m 0.46 km
	Sedan	1000 lbs 454 kg	400 ft 0.08 miles 122 m 0.12 km	1750 ft 0.33 miles 533 m 0.53 km
	Passenger van Cargo van	4000 lbs 1814 kg	600 ft 0.11 miles 183 m 0.18 km	2750 ft 0.52 miles 838 m 0.84 km
	Small moving truck Delivery truck	10,000 lbs 4536 kg	860 ft 0.16 miles 262 m 0.26 km	3750 ft 0.71 miles 1143 m 1.14 km

Table 7-2 Explosive Threat Evacuation Distances—Cont'd

Explosive Threats		Explosives Capacity[a]. TNT Equivalent in Pounds and Kilograms	Building Evacuation Distance[b]	Outdoor Evacuation Distance[c]
	Moving van Water truck	30,000 lbs 13,608 kg	1240 ft 0.24 miles 378 m 0.38 km	6500 ft 1.23 miles 1981 m 1.98 km
	Semitrailer	60,000 lbs 27,216 kg	1500 ft 0.28 miles 457 m 0.46 km	7000 ft 1.33 miles 2134 m 2.1 km

[a]Based on the estimated maximum quantity or weight of explosives (or the corresponding amount of TNT) that could realistically be placed in a device or vehicle.
[b]Recommended safe distances from outdoor explosions for those in nearby buildings is difficult to accurately determine due to the number of variables, including building materials, type of structure, etc. These estimates are based on typical US commercial construction materials.
[c]There may still be risks for individuals inside buildings who are within the outdoor evacuation distance.
NOTE: Safe outdoor distances are estimated based upon how far fragments are likely to be thrown. Pipe, briefcase, and backpack bombs are often designed to project fragments which may travel farther, relative to the volume of explosive, than for those of explosives in vehicles.
Adapted from information provided by the US National Counterterrorism Center. Available at: http://www.nctc.gov/docs/2006_calendar_bomb_stand_chart.pdf.

Response and Recovery

It is important for all first responders to be aware of risks when approaching a potential bombing or industrial explosion scene. In addition to the bombing threat posed by a suspect device, secondary devices are a common way to strike at responders. Even if an explosion has already occurred, it is important to consider the possibility of residual explosive material in the immediate area of the blast, or an intentional device intended to be detonated when the response is underway (Suprun, 2004). Similarly for industrial explosions, residual explosion risks may exist in the aftermath of an incident. A triage area should be established upwind from the immediate incident area to minimize the possible exposure to inhalation hazards resulting from a blast. If it is a suspected terrorist explosion, these hazards include chemical, biological, or radiological substances introduced with the explosive device to complicate the response and inflict greater injury. As at any mass trauma scene, the dead and injured may pose blood-borne pathogen hazards, including HIV and hepatitis B. There is an assortment of hazardous building substances which can be released from an explosion as well. This includes particles such as asbestos, lead, silica, fiberglass, and a variety of chemical by-products from burning material.

According to the Centers for Disease Control and Prevention, there are several essential concepts caregivers need to keep in mind concerning provision of care to those injured in explosions (CDC, 2003):

1. There will be unique injury patterns usually only seen in combat situations.
2. The most common injuries will be penetrating and blunt traumas.

3. The most common lethal injury among those who initially survive is "blast lung."
4. Explosions in confined spaces of buildings or transportation systems have higher morbidity and mortality.
5. Structural collapse following an explosion also results in higher morbidity and mortality.
6. Half of all casualties will seek care in the first hour.
7. The number of casualties seen in the first hour at the hospital is a useful predictor of how many more are expected to come.
8. Expect an "upside-down" triage. The less-injured will often arrive at the hospital before the more critical.

Local public health agencies also have an important role in the long-term monitoring and follow-up of survivors. If hazardous materials are released by an explosion, including chemical, biological, or radiological material, a public health agency can establish a registry to track the long-term mental and physical health effects associated with the event. An excellent example of a large disaster health registry is the World Trade Center (WTC) Health Registry. This registry monitors the physical and emotional health impact of the 2001 WTC collapse for 20 years by periodically collecting and analyzing information on over 71,000 enrollees exposed to the aftermath of the WTC collapse (Brackbill et al., 2006). This provides a mechanism to communicate with the affected population and answer important questions regarding their health. The registry is also used to inform those enrolled about new treatments as they become available and to facilitate research which makes current information on how to identify and treat associated conditions available to healthcare providers.

Summary

In recent years, bombings have become more sophisticated and lethal. If recent trends continue, it is likely that bombings will occur in nations in which they have not previously occurred. This creates tremendous challenges for both the general public and response communities. Security personnel for high-risk buildings must consider the physical security measures and determine if these measures adequately address the threat of a bomb being mailed, carried, or driven into the building. Measures may be taken to enhance the ability to screen incoming persons and mail for suspicious materials, and distance must be established between vehicle access and buildings. Everyone at risk needs to understand the proper approach to a bombing threat and be able to carry out effective threat identification, reporting, and occupant evacuation. Those working in the first responder and healthcare communities also must be aware of the differences between a bomb scene and other disasters. The risks are unusual, the patients are different, and the steps taken to properly manage the scene are distinctive. Reducing morbidity and mortality associated with these threats requires careful planning, training, and execution.

Industrial explosion preparedness has similar preparedness and response challenges requiring physical security threat assessments, preparedness planning, and employee

training. Exercises and drills reinforce appropriate front line worker behavior and response actions. In addition, industries with explosion risks should begin mitigating risk in the initial stages of process design. Tools such as the FE&I are useful in characterizing and ranking explosion and fire risks through process analysis and evaluation of associated materials. With the continued expansion of global industrialization, there are increasing number of facilities posing explosion risks for workers and the surrounding community. Public health and healthcare institutions in these communities must consider the unique challenges of explosion preparedness and response in their efforts to make communities safer and more resilient.

Websites

American College of Emergency Physicians, Clinical Practice and Management, Bombings: Injury Patterns and Care, Resources for Physicians. http://www.acep.org/blastinjury/.

American Red Cross, Terrorism Preparedness. http://www.redcross.org/prepare/disaster/terrorism.

Centers for Disease Control and Prevention, Bombings: Injury Patterns and Care, Blast Injury Training. www.bt.cdc.gov/masscasualties/bombings_injurycare.asp.

Centers for Disease Control and Prevention, Blast Injury Mobile Application. https://itunes.apple.com/au/app/cdc-blast-injury/id890434999?mt=8&ign-mpt=uo%3D2.

Centers for Disease Control and Prevention, Explosions and Blast Injuries: a Primer for Clinicians. http://www.cdc.gov/masstrauma/preparedness/primer.pdf.

Centers for Disease Control and Prevention, In a Moment's Notice: Surge Capacity in Terrorist Bombings. www.bt.cdc.gov/masscasualties/pdf/surgecapacity.pdf.

Centers for Disease Control and Prevention, Hospital Preparedness and the Boston Marathon bombing. http://blogs.cdc.gov/publichealthmatters/2013/09/hospital-preparedness-and-the-boston-marathon-bombing/.

Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF): Explosives. https://www.atf.gov/content/explosives.

Department of Justice, Federal Bureau of investigation (FBI), Explosives Unit (EU). https://www.fbi.gov/about-us/lab/terrorist-explosive-device-analytical-center-tedac/eu.

Department of Justice, Office of Justice Programs, June 2000. A Guide for Explosion and Bombing Scene Investigation. www.ncjrs.gov/pdffiles1/nij/181869.pdf.

Department of Transportation, Transit Security Design Considerations. http://transit-safety.volpe.dot.gov/security/SecurityInitiatives/DesignConsiderations/CD/ftasesc.pdf.

Federal Emergency Management Agency, Bomb threat call procedures. https://emilms.fema.gov/is906/assets/ocso-bomb_threat_samepage-brochure.pdf.

Federal Emergency Management Agency, Explosion Preparedness. http://www.ready.gov/explosions.

Federal Emergency Management Agency, Emergency Management Guide for Business and Industry: A Step-by-Step Approach to Emergency Planning, Response and Recovery for Companies of All Sizes. http://www.fema.gov/pdf/library/bizindst.pdf.

Journal of Emergency Medical Services, EMS Disaster Preparedness for Natural Gas Explosions. http://www.jems.com/articles/2011/11/ems-disaster-preparedness-natural-gas-ex.html.

Medscape, B. Injuries. http://emedicine.medscape.com/article/822587-overview.

National Academies and U.S. Department of Homeland Security, Factsheet, IED Attack: Improvised Explosive Devices. http://www.dhs.gov/xlibrary/assets/prep_ied_fact_sheet.pdf.

National Counterterrorism Center, Bomb threat Stand-off distances. http://www.nctc.gov/site/technical/bomb_threat.html.

United States Postal Service, Handling and processing mail Safely. http://about.usps.com/publications/pub166/pub166_tech_015.htm.

References

Adler, J., Golan, E., Golan, J., Yitzhaki, M., Ben-Hur, N., 1983. Terrorist bombing experience during 1975–1979. Casualties admitted to the Shaare Zedek Medical Center. Isr. J. Med. Sci. 19, 189–193.

A+E Networks (AE), 2009. Fertilizer explosion kills 581 in Texas. This Day in History, 1947. Available at: http://www.history.com/this-day-in-history/fertilizer-explosion-kills-581-in-texas.

Anderson, G.V., Feliciano, D.V., 1997. The Centennial Olympic Park bombing: Grady's response. J. Med. Assoc. Ga. 86, 42–46.

Barras, C., June 3, 2008. Glowing Spray Lets CSI Operatives 'dust' for Explosives. NewScientist.com. Available at: http://www.newscientist.com/article/dn14048-glowing-spray-lets-csi-operatives-dust-for-explosives.html#.VZg-J_lViko.

BBC News, 2005a. Special Report, London Attacks, 7 July Bombings. Available at: http://news.bbc.co.uk/2/shared/spl/hi/uk/05/london_blasts/what_happened/html/default.stm.

BBC News, 2005b. Obituary: Anat Rosenberg. BBC News. August 3, 2005 http://www.bbc.com/news/uk-12207400.

Bellamy, R.F., Zajtchuk, R., 1991. The Physics and Biophysics of Wound Ballistics. Chapter 4 in Conventional Warfare: Ballistic, Blast, and Burn Injuries. Office of the Surgeon General of the U.S. Army, Washington, DC, pp. 107–118.

Benzinger, T., 1950. Physiological effects of blast in air and water. In: German Aviation Medicine World War II, vol. 2. U.S. Government Printing Office, Washington, DC, pp. 1225–1259.

Brackbill, R.M., Thorpe, L.E., DiGrande, L., et al., 2006. Surveillance for World Trade Center disaster health effects among survivors of collapsed and damaged buildings. MMWR Surveill. Summ. 55 (2), 1–18. Available at: www.cdc.gov/mmwr/preview/mmwrhtml/ss5502a1.htm.

Brismar, B., Bergenwald, L., 1982. The terrorist bomb explosion in Bologna, Italy, 1980: an analysis of the effects and injuries sustained. J. Trauma 22, 216–220.

Centers for Disease Control and Prevention (CDC), May 9, 2003. Explosions and Blast Injuries: A Primer for Clinicians. Available at: http://www.cdc.gov/masstrauma/preparedness/primer.pdf.

Chicago Tribune (CT), December 6, 1948. Chinese Ship Blast with Loss of 6,000 Lives Is Revealed. Available at: http://archives.chicagotribune.com/1948/12/06/page/22/article/chinese-ship-blast-with-loss-of-6-000-lives-is-revealed.

Coppel, D.L., 1976. Blast injuries of the lungs. Br. J. Surg. 63, 735–737.

de Candole, C.A., 1967. Blast injury. Can. Med. Assoc. J. 96, 207–214.

Fire Prevention and Engineering Bureau of Texas (FPEB), April 16, 1947. Texas City, Texas, Disaster. Available at: http://www.local1259iaff.org/report.htm.

Frykberg, E.R., 2003. Medical management of disasters and mass casualties from terrorist bombings: how can we cope? J. Trauma 53, 201–212.

Frykberg, E.R., Tepas, J.J., Alexander, R.H., 1989. The 1983 Beirut airport terrorist bombing: injury patterns and implications for disaster management. Am. Surg. 55, 134–141.

Hadden, W.A., Rutherford, W.H., Merrett, J.D., 1978. The injuries of terrorist bombing: a study of 1532 consecutive patients. Br. J. Surg. 65, 525–531.

Institute for Economics and Peace (IEP), 2014. Global Terrorism Index 2014. Available at: http://economics-andpeace.org/research/iep-indices-data/global-terrorism-index.

Johnstone, D.J., Evans, S.C., Field, R.E., Booth, S.J., 1993. The Victoria bomb: a report from the Westminster hospital. Injury 24, 5–9.

Katz, E., Ofek, B., Adler, J., Abramowitz, H.B., Krausz, M.M., 1989. Primary blast injury after a bomb explosion in a civilian bus. Ann. Surg. 209, 484–488.

Kurt, K., April 17, 2005. A Lasting Imprint: Photo Defined Oklahoma City Tragedy for the World, but Mother, Photographer Still Search for Meaning. The Standard Times.

Leibovici, D., Gofrit, O.N., Shapira, S.C., 1999. Eardrum perforation in explosion survivors: is it a marker of pulmonary blast injury? Ann. Emerg. Med. 34, 168–172.

Mallonee, S., Shariat, S., Stennies, G., Waxweiler, R., Hogan, D., Jordan, F., 1996. Physical injuries and fatalities resulting from the Oklahoma city bombing. JAMA 276, 382–387.

McLain, S.R., 1995. The Oklahoma City Bombing: Lessons Learned by Hospitals. Oklahoma Hospital Association, Oklahoma. Available at: http://www.aha.org/content/00-10/OKCBombing.pdf.

Mellor, S.G., Cooper, G.J., 1989. Analysis of 828 servicemen killed or injured by explosion in Northern Ireland 1970–84: the hostile action casualty system. Br. J. Surg. 76, 1006–1010.

Moore, D.S., 2007. Recent advances in trace explosives detection instrumentation. Sens. Imaging Int. J. 8 (1), 9–38.

New York Times (NYT), April 17, 1947. Blasts and Fires Wreck Texas City of 15,000; 300 to 1,200 Dead; Thousands Hurt, Homeless; Wide Coast Area Rocked, Damage in Millions. Available at: http://www.nytimes.com/learning/general/onthisday/big/0416.html#article.

Nixon, R.G., Stewart, C., 2004. When things go boom: blast injuries. Fire Eng. 2.

Oklahoma City National Memorial & Museum (OCNMM), 2015. Those Who Were Killed. Available at: https://oklahomacitynationalmemorial.org/people/.

Pearce, T.C., Schiffman, S.S., Nagle, H.T., Gardner, J.W. (Eds.), 2002. Handbook of Machine Olfaction: Electronic Nose Technology. Wiley-VCH, Weinheim.

Phillips, Y.Y., 1986. Primary blast injuries. Ann. Emerg. Med. 15 (12), 1446–1450.

Phillips, Y.Y., Richmond, D.R., 1991. Primary Blast Injury and Basic Research: Brief History. Chapter 6 in Conventional Warfare: Ballistic, Blast, and Burn Injuries. Office of the Surgeon General of the U.S. Army, Washington, DC, pp. 221–240.

Quenonmoen, L.E., Davis, Y.M., Malilay, J., Sinks, T., Noji, E.K., Klitzman, S., 1996. The World Trade Center bombing: injury -prevention strategies for high-rise building fires. Disasters 20, 125–132.

Rose, D., May 18, 1990. Devices Reveal IRA Know-How. The Guardian London.

Soraghan, M., October 21, 2014. The drilling industry's explosion problem. Environ. Energy News. Available at: http://www.wyofile.com/drilling-industrys-explosion-problem/.

Stein, M., Hirshberg, A., 1999. Medical consequences of terrorism: the conventional weapons threat. Surg. Clin. North Am. 79 (6), 1537–1552.

Suprun, S.C., 2004. Explosive events: EMS response to a bombing incident. Emerg. Med. Serv. 33 (4), 61–65.

U.S. Department of State, 1998. Report of the Accountability Review Boards on the Embassy Bombings in Nairobi and Dar es Salaam on August 7, 1998. Available at: http://1997-2001.state.gov/www/regions/africa/accountability_report.html.

Waco-McLennan County Public Health District (WMCPHD), Waco, TX and Texas Department of State Health Services (DSHS), June 24, 2014. A Public Health Report on Injuries Related to the West (Texas) Fertilizer Plant Explosion, April 2013. Available at: http://www.waco-texas.com/userfiles/cms-health-department/file/pdf/West-Texas-Report-6-2014.pdf.

Wightman, J.M., Gladish, S.L., 2001. Explosions and blast injuries. Ann. Emerg. Med. 37, 664–678.

8

Chemical Hazards and Disasters

OBJECTIVES

- Explain the dose–response relationship and how chemicals can enter the body.
- List the physical, physiological, and environmental factors influencing exposures.
- Recognize the various systems used to classify and label chemical threats.
- Explain the difference in values between occupational and accidental chemical exposure guidelines.
- Describe the similarities and differences between chemical accidents and chemical terrorism.
- List the unique treatment requirements for chemical terrorism agents.
- Describe how a community prepares for and reduces the impact of chemical emergencies and disasters.
- List indicators suggesting that a chemical release may have occurred.
- Explain appropriate individual actions when notified of a chemical release in the community.
- Describe populations with the greatest risks of chemical exposure and why each has such risk.

Introduction: Train Accident and Chlorine Gas Leak, Graniteville, South Carolina, 2005

In the early morning hours of January 6, 2005, Graniteville, South Carolina experienced a catastrophic train derailment and chemical release. The night before, a local train engineer parked his locomotive and two train cars on a rail spur just off the main rail line running through town. Early the next morning a Norfolk Southern train with two locomotives and 42 rail cars departed Augusta, Georgia, bound for Columbia, South Carolina. Among the rail cars in tow were several pressurized tank cars filled with over 200 tons of liquid chlorine. As the train entered the small town of Graniteville, South Carolina, something went horribly wrong. A rail switch was locked in the wrong position, directing oncoming trains off the main line and onto the spur where the stationary train sat from the night before. Realizing what was happening, the engineer applied the emergency brake, but it was too late. The train cars derailed, rupturing the tanks of chlorine and releasing a cloud of deadly green gas across the community (see Fig. 8-1) (Hart and Wald, 2005; NTSB, 2005). The train engineer died at the scene, and eight more people died from the initial release. Most of the fatalities were night shift workers at nearby Avondale Mill. While some made it to their cars and sped away as others stayed inside the building, still others tried to outrun the cloud on foot. A couple of them were found dead in a nearby wooded area. An additional 529 people sought care for possible exposure. Of those, 511 were seen in area emergency departments and 69 were hospitalized (CDC, 2005b). The tragic chlorine release in Graniteville accentuates the widespread vulnerability we all have to industrial chemical

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FIGURE 8-1 A collision of two freight trains in Graniteville, South Carolina on January 6, 2005, resulted in the release of chlorine gas into the atmosphere. *US Environmental Protection Agency.*

disasters. Though some in Graniteville died at or near the mill, the remaining fatalities included a truck driver sleeping in his cab, a man who drove through the cloud returning home from a convenience store, and even a nearby resident who never left his home. Thousands were evacuated and dozens were seen in local hospitals. Many continue to have chronic respiratory problems.

What Went Right with the Graniteville Accident Response and Recovery?

Officials in South Carolina quickly declared a state of emergency and evacuated several thousand residents. Local businesses and schools were closed, and coordination with state and federal responders brought resources into the area to better manage the scene. A coordinated community assessment was carried out, including an environmental assessment with the assistance of the Environmental Protection Agency as well as a rapid epidemiological assessment with the assistance of the Centers for Disease Control and Prevention. Good communication was established with the community, and resources were developed ranging from fact sheets about reentering the home after the evacuation to tips on taking care of pets that were left behind (CDC, 2005b; EPA, 2005).

Chlorine is a widely used industrial chemical. Applications include everything from purifying water to making plastics. Chlorine was used as a chemical warfare agent on the battlefield in World War I, and more recently has been used as a weapon by insurgents and terrorists in Iraq, who often place cylinders of chlorine in car bombs to injure more people and complicate the response (Cave and Fadam, 2007; Morris, 2014).

In addressing preparedness and response to chemical disasters and hazardous material (hazmat) releases, it is important to note that preparing for toxic industrial chemical accidents is very similar to preparing for chemical terrorism. One release is accidental and the other is intentional, but the resulting human impact can be the same.

There is no place where people live or work that is completely free from the risks of hazardous chemical exposures. Toxic industrial chemicals are stored and used in large quantities across highly populated areas. They are also transported in large quantities on trucks or trains through nearly every rural town on the map. This chapter addresses chemical emergency preparedness on two levels, beginning with chemical risks originating outside the home and then focusing on those within.

Chemical Disaster Definitions

Acute exposure guideline levels Estimated concentrations of a chemical that a healthy person may be safely exposed to for 10 minutes, 30 minutes, 60 minutes, 4 hours, or 8 hours during an emergency. These values are used to make decisions about evacuation.

Acute poisoning A one-time high-dose exposure during a short period, resulting in a fast severe response.

Biotoxin A poisonous substance derived from a living organism.

Blister agent Also called a vesicant; a substance which produces chemical burns and blisters when it comes in contact with the skin or mucous membranes.

Blood agents Substances, such as cyanide compounds, that prevent cells from using oxygen.

Carcinogen A substance initiating or promoting cancer.

Choking agents Substances, such as chlorine, which cause severe damage to the respiratory tract and can result in suffocation.

Chronic poisoning A prolonged exposure over a longer period, resulting in illness that is often more difficult to identify than with an acute exposure.

Corrosive A highly reactive substance, such as an acid or alkaline, that causes damage to living tissue.

Cumulative effect A reaction occurring over a longer period of time following multiple exposures.

Emergency response planning guidelines (ERPGs) Estimated concentrations of a chemical a healthy person can be exposed to for up to 1 hour during an emergency.

Local effect A reaction to an exposure observed at the specific sites on the body.

Nerve agents Substances, such as sarin, which interfere with the proper function of the nervous system.

Oxidizer A substance that reacts with other materials by providing an oxygen source. This can stimulate combustion in organic materials.

Synergistic effect A reaction of two or more chemicals that is greater than the sum of the two individual exposures.

Systemic effect A reaction to an exposure involving the whole body or multiple body systems.

Chemical Health Threats

Chemical toxicity is the ability of a chemical molecule or compound to damage susceptible sites or cells in the human body or in other living biological systems, including plants, animals, or ecosystems. The toxicity or harmful reaction from a chemical exposure is referred to as the "response." The amount of a chemical the body is exposed to is called the "dose." Assessing the amount of damage to biological systems is called the dose–response

relationship. An illness-causing or lethal dose of a chemical can enter the body through the lungs, skin, gastrointestinal tract, or mucous membranes. Multiple means of entry can also complicate the disposal process.

Environmental specialists carefully dispose of chemicals spilled during Hurricane Rita. *Federal Emergency Management Agency photo by Marvin Nauman.*

Chemical Exposure Factors

The route and rate of an exposure determines the dose received. The results can include *acute poisoning*, which is a rapid absorption resulting in an especially fast and severe response. Examples of lethal acute exposures include substances such as cyanide and carbon monoxide. Morbidity and mortality results from a single exposure, multiple intermittent doses in a 24-hour period, or continuous exposure over several hours. There are also *chronic poisonings* resulting from prolonged exposures over longer periods ranging from days to years. The symptoms of chronic poisonings are often far less apparent. This is especially true for chronic low-level exposures to heavy metals such as lead and mercury which can accumulate in the body for years and cause slow incremental damage.

Exposure Factors

1. dose
2. time of exposure
3. route of exposure
4. physical characteristics of chemical substance
5. previous or simultaneous exposures to other chemical substances
6. environmental conditions

7. physiological characteristics of the exposed individual
   a. genetics
   b. age
   c. race
   d. health status
   e. lifestyle

A variety of factors determine toxicity and poisoning outcomes. Depending on the characteristics of the substance, the dose required for toxicity is variable. Substances that are highly toxic per unit of weight do not require large doses for significant health effects. Some exposures display a *local effect*, a specific reaction observed at the site of an exposure. A local effect occurs in the respiratory tract with chlorine exposure or on the skin with corrosives. Some chemicals also have a *systemic effect*. This is when a chemical affects a system at a site other than the point of exposure after it has been absorbed and circulated to the target organ. For example, benzene can be absorbed through the skin or the lungs. Once it is in the bloodstream, it is converted to damaging metabolites in the liver and bone marrow. There is also a *cumulative effect* with many chemicals, particularly heavy metals, where the signs and symptoms are usually observed after numerous or continuous exposures over a period of time. A *synergistic effect* occurs when two or more chemicals combine in a response greater than the two individual chemicals by themselves. The classic example of this chemical synergy is seen in the abuse of certain drugs and alcohol.

The physical properties of a chemical are also important factors. The state of a substance (liquid, solid, or gas) influences the route of exposure. If the substance is a solid, the size determines where a substance will be deposited in the airway if inhaled. Larger particles are trapped in the upper airways, and smaller particles (3–5 μm) are more likely to go deeper into the lungs. Previous chemical exposures can result in an increased sensitivity or tolerance. Environmental conditions such as temperature and humidity influence exposure. Some chemicals are poorly absorbed in high humidity, while others are more easily absorbed. Lipids and lipid-soluble substances absorb more readily. The existing state of health, genetics, age, race, gender, and lifestyle can influence the toxicity of chemical exposures. Smoking destroys protective airway cilia, which can allow larger particles to descend deeper into the respiratory tract. Chronic or concomitant use of alcohol impacts the metabolism of some chemicals in the liver and can alter their toxicity.

Categorization and Measurement of Chemical Health Threats

Historically, there have been a variety of ways various industries around the world categorize chemical threats to human health. The US classification and communication of chemical hazards is a responsibility shared by multiple agencies. Although the physical characteristics of a chemical can be defined clearly and objectively with measurements such as vapor pressure or specific gravity, health hazards are far more difficult to

categorize and define. It is difficult to develop concise measurements of things such as irritant properties or other highly subjective parameters. As a result, there are a myriad of far less precise titles and definitions for health hazards. Chemical contamination effects are communicated through standardized labels, placards, and material safety data sheets. As national economies continue toward globalization, divergent labeling practices pose increasing safety challenges and difficulties in communicating chemical hazard information for imported and exported materials. The United Nations Economic and Social Council adopted the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) in 2003 (Fig. 8-2). This United Nations work is an effort to get as many nations as possible to voluntarily standardize, or harmonize, the way in which the chemical hazards are classified and communicated (UN, 2007). Understanding hazard communication systems is a critical factor in protecting public health. The European Union European Chemicals Agency adopted the Classification, Labeling, and Packaging (CLP) Regulations in January, 2009, in order to align earlier EU legislation on the CLP of chemicals to the GHS. The US Occupational Safety and Health Administration (OSHA) promulgated a new rule in March 2012 requiring the workplace Hazard Communication Standards adopt the GHS for the classification and labeling of chemicals (Bachman, 2013).

Globally Harmonized System of Human Health Classes

The GHS includes 10 classes of chemical threats to human health. Each class has established criteria with numeric thresholds placing each substance in a category conveying the hazard level. For example, acute toxicity is based on how toxic a substance is when ingested, inhaled, or placed on the skin. An acute toxicity estimate value is calculated based on the available toxicity data. The results are used to place a substance in a hazard category ranging from 1 through 5. Category 1 agents are the most toxic, and Category 5 agents are the least hazardous. A similar categorization is carried out for all 10 classes of health effects. However, not all classes have five categories. “Skin corrosion” includes three categories, while “specific target organ systemic toxicity-repeated exposures” only has two categories. The latter includes Category 1 substances known to cause damage to specific organs and Category 2 substances which possibly cause damage to specific organs (UN, 2007).

Globally Harmonized System of Human Health Hazard Classes

1. Acute toxicity
2. Skin corrosion/irritation
3. Serious eye damage/irritation
4. Respiratory or skin sensitization
5. Germ cell mutagenicity
6. Carcinogenicity

7. Reproductive toxicity
8. Specific target organ systemic toxicity: single exposure
9. Specific target organ systemic toxicity: repeated exposure
10. Aspiration hazard

Globally Harmonized System of Classification and Labeling of Chemicals (GHS), Program (UN, 2007).

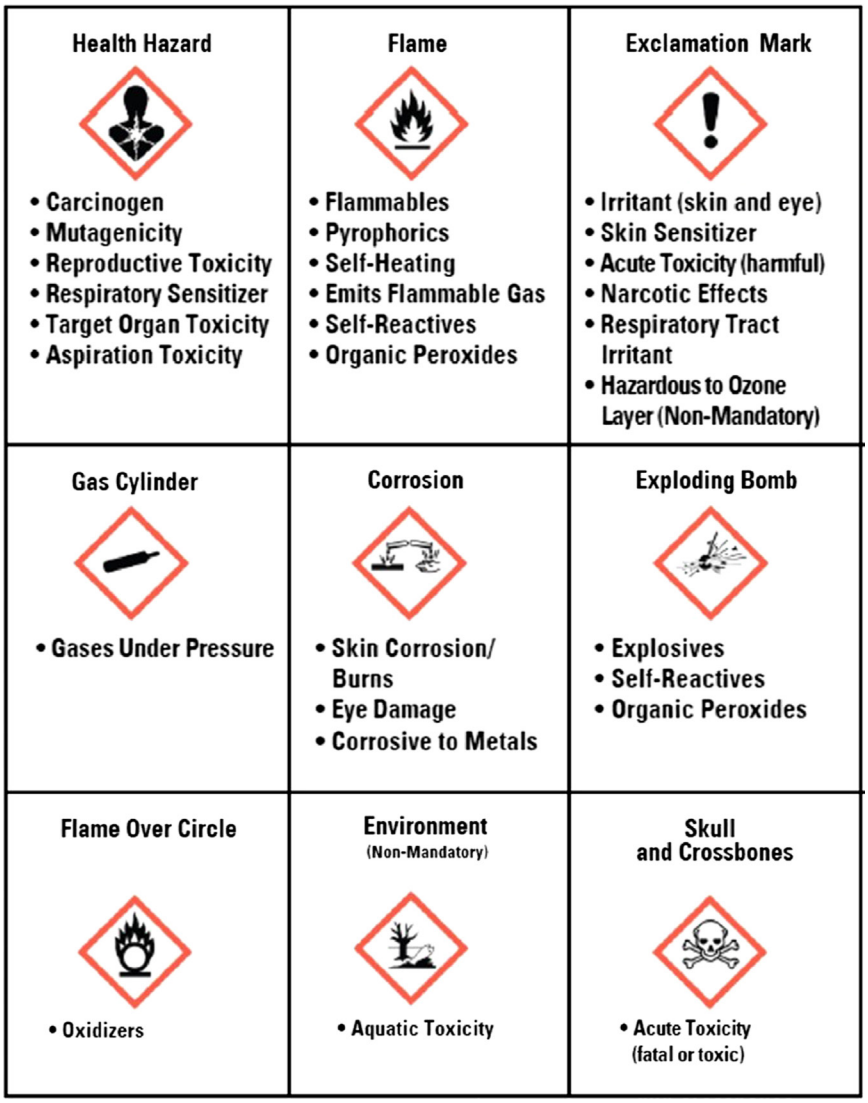

FIGURE 8-2 Globally harmonized system labels. *Globally Harmonized System of Classification and Labeling of Chemicals (GHS), Annex 2, Classification and Labeling Summary Tables (UN, 2007).*

National Fire Protection Association (NFPA) 704M System of Communicating Hazards

The individuals at greatest risk for hazmat exposure are first responders. Any time a transportation accident or damage at an industrial operation occurs, it is essential for responders to have rapid, clear communication of the potential hazards they could encounter. One system currently used in the United States, NFPA 704M, was developed through the National Fire Protection Association (NFPA) (Fig. 8-3). In this system a simple placard is placed on a container or facility to communicate the nature of the substances inside so first responders can take the proper precautions before handling the material or entering the facility during an emergency. The system uses a large diamond sign, called the "fire diamond," comprising four smaller diamonds, each having a different primary color. A large number is placed in one or more of the diamonds to indicate the nature and level of risk. Red indicates flammable hazards, yellow denotes reactive hazards, white signifies special hazards, and blue signals health hazards. A number of 0 through 4 is placed in each diamond, except the white one, which uses letters, to communicate the level of risk. For example, a blank blue diamond indicates there are no substances posing health hazards, and a four indicates extremely toxic materials. A zero in the red diamond indicates there is no flash point for the material inside, whereas a 1 in the red diamond indicates the presence of materials with a flash point more than 200°F, and a 4 indicates a flash point less than 73°F. The yellow diamond communicates reactive materials and the degree to which they can explode when heated, disturbed by mechanical shock, or by coming in contact with water. Finally, if the white diamond at

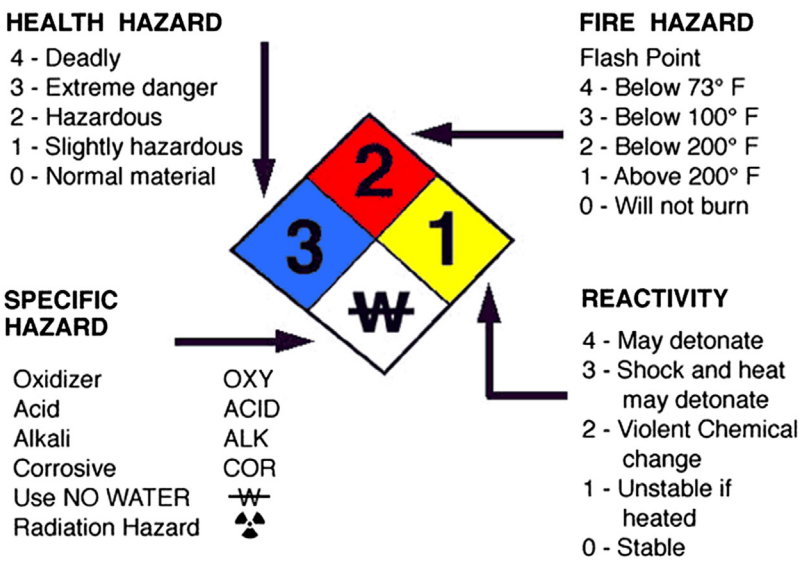

FIGURE 8-3 National Fire Protection Association 704M system "fire diamond." *National Fire Protection Association.*

the bottom is blank, there are no specific or special hazards present. If there are specific hazards, an abbreviation will be placed in the box such as CA for carcinogens, CO for corrosives, T for toxins, etc. (NFPA, 2007).

Improper Hazmat Labeling—A Worst Case Scenario from Flight 592

Walter Hyatt was a songwriter and performed for many years with "Uncle Walt's Band" in Austin, Texas. Although they never experienced commercial success, their following grew in the 1970s and included people around the world and some noteworthy Americans such as Lyle Lovett, a young college student at the time, who would later experience huge commercial music success and become friends with the band members, including Walter. It was a clear day as Walter boarded a plane. He was on his way home after attending his daughter's wedding in Miami. It was May 11, 1996, when he boarded ValuJet flight 592 (Everitt, 2004). It was a DC-9 passenger plane destined for Atlanta with 105 passengers plus a crew of five. About 10 minutes after taking off from Miami, the pilot called in an emergency. There was smoke in the cabin and the cockpit. The flight was immediately cleared to return to Miami International Airport but never made it. They crashed in the everglades and no survivors were recovered. The loss of Walter and the other 109 people on Flight 592 was attributed to poor labeling of a hazmat. Poorly labeled, expired oxygen generators were being shipped in a cargo container on the flight along with other materials. When the oxygen generators are in use, they are safely mounted above each passenger seat and are activated when the emergency masks drop from the ceiling. Although they produce heat and release oxygen, the generators activate safely when they are in place. If they are packaged in bulk for shipping, they present a very different hazard. This shipment of expired generators was identified as the cause of the tragic accident. According to the National Transportation Safety Board report, "…had a warning label or emblem clearly indicating the significant danger posed been affixed to each generator, personnel handling the generators, including the personnel in the shipping and stores who prepared them for shipment to Atlanta, might have been alerted to the need to determine how to safely handle and ship the generators. Had they done so, they might have learned of the need for (and acquired) safety caps and they might also have learned that the unexpended generators demand special packaging and identification requirements (and taken appropriate actions). Even if they did one of these actions, the accident would not likely have occurred" (NTSB, 1997).

US Department of Transportation (DOT) Labeling System

The US Department of Transportation (DOT) hazard labeling system also uses color-coded diamonds to display the major hazard associated with material in transport (Fig. 8-4). These placards use a combination of key words, color, and numeric classes to designate the nature of hazmats in transport. They are similar to those of the GHS, as they assign classifications and communicate hazards. The DOT placards focus on transportation safety, whereas the GHS labeling focuses on occupational health and safety. DOT divides hazards into one of nine classes. For example, the DOT categorizes flammable liquids as

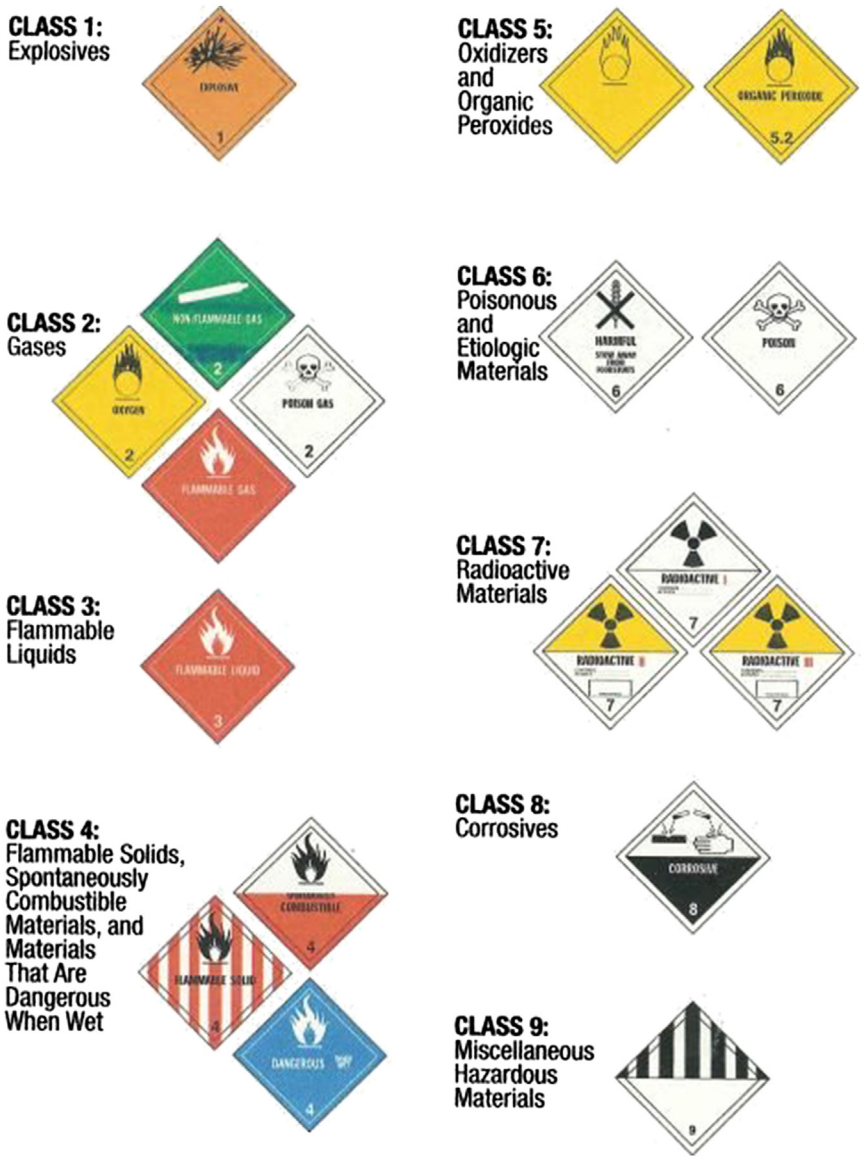

FIGURE 8-4 US Department of Transportation hazardous materials warning labels. *US Department of Transportation.*

"Class 3"; GHS simply names the flammable liquid with no numeric qualifiers. There are also health hazards classifications under GHS not included under the DOT, including:

1. respiratory or skin sensitization
2. germ cell mutagenicity
3. carcinogenicity generally

4. reproductive toxicity (teratogenicity)
5. specific organ toxicity

Centers for Disease Control and Prevention Hazardous Chemical Nomenclature

In addition to the differing placards and labels used in the United States and in other nations, there continue to be fundamental differences in the nomenclature of various hazards. Categories commonly used by American health and safety professionals often divide hazardous chemicals by their basic structure or composition, such as solvents or metals. There are also chemicals categorized based on their target organs or physiological damage. These include nerve, blister, and pulmonary agents. There is no definite pattern or trend that determines which term or label is most acceptable. The terms most commonly used today have emerged from various disciplines such as defense, emergency medicine, and the chemical industry over many years. No categorization list is exclusive. The Centers for Disease Control and Prevention (CDC) uses a combination of categorical titles to describe the health systems affected, the symptoms produced, and the chemical structure.

CDC Hazardous Chemical Categories

1. Biotoxins: poisons derived from plants or animals
2. Blister agents/vesicants: chemicals that severely blister the eyes, respiratory tract, and skin
3. Blood agents: chemicals affecting the body when absorbed into blood
4. Caustics (acids): chemicals that burn or corrode the skin, eyes, and mucous membranes of the nose, mouth, throat, and lungs
5. Choking/lung/pulmonary agents: chemicals that cause severe irritation or swelling of the respiratory tract including the nose, throat, and lungs
6. Incapacitating agents: drugs that alter thinking and consciousness, sometimes leading to unconsciousness
7. Long-acting anticoagulants: poisons that prevent blood from clotting properly and lead to uncontrolled bleeding
8. Metals: poisons that consist of metallic agents such as lead, arsenic, and mercury
9. Nerve agents: chemicals that prevent the nervous system from working properly
10. Organic solvents: chemicals that damage the tissues of living things by dissolving fats and oils
11. Riot control agents/tear gas: highly irritating nonlethal chemicals used by law enforcement for crowd control, such as tear gas, or by individuals for protection, such as mace or pepper spray
12. Toxic alcohols: poisonous alcohols that can damage the heart, kidneys, and nervous system
13. Vomiting agents: chemicals that cause nausea and vomiting

Centers for Disease Control and Prevention (CDC, 2013a).

In the US Code of Federal Regulations (29 CFR, 1910.1200, Appendix A), OSHA uses categorical descriptors related to workplace exposures such as carcinogens, irritants, and sensitizers. OSHA also categorizes chemical exposures according to specific organ systems, such as hepatotoxins which damage the liver or teratogens which produce birth defects. This is in contrast to the CDC nomenclature. The difference is a product of the particular focus of each agency. OSHA is focused on regulatory enforcement across a variety of industries, whereas CDC is sharing facts and reference materials for public health and healthcare organizations. When engaging in preparedness and response activities it is important to be mindful of the overall mission of each agency. Because the CDC has a public health and medical focus, they are more likely to have more current health information. OSHA is focused more on enforcement of standards to protect the workforce from long-standing occupational hazards and is less likely to have current health information for emerging public health issues.

OSHA Health Hazard Definitions

1. Carcinogens—chemicals suspected of or known to produce cancer, including substances:
   a. acknowledged by the International Agency for Research on Cancer to be a carcinogen or potential carcinogen
   b. listed as a carcinogen or potential carcinogen in the *Annual Report on Carcinogens* published by the National Toxicology Program (latest edition)
   c. regulated by OSHA as a carcinogen
2. Corrosives—chemicals causing visible damage or destruction of living tissue by chemical action at contact site
3. Highly toxic chemicals—a chemical that:
   a. has a median lethal dose, LD_{50} (killing 50% of test rats), of 50 mg or less per kilogram of body weight when administered orally
   b. has a median lethal dose, LD_{50}, of 200 mg or less per kilogram of body weight when administered by continuous contact for 24 hours or less
   c. has a median lethal concentration dose, LC_{50}, in the air of 200 parts per million by volume or less of gas or vapor, or 2 mg per liter or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour
4. Irritants—chemicals which are noncorrosive, but which cause reversible inflammatory effects on living tissue by chemical action at the contact site
5. Sensitizers—chemicals which cause a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure
6. Toxic chemicals—a chemical that:
   a. has a median lethal dose, LD_{50}, of more than 50 mg per kilogram but not more than 500 mg per kilogram of body weight when administered orally
   b. has a median lethal dose, LD_{50}, of more than 200 mg per kilogram but not more than 1000 mg per kilogram of body weight when administered by continuous contact for 24 hours or less
   c. has a median lethal concentration dose, LC_{50}, in air of more than 200 parts per million but not more than 2000 parts per million by volume of gas or vapor, or more than 2 mg per liter but not more than 20 mg per liter of mist, fume, or dust, when administered by continuous inhalation for 1 hour or less

7. Chemicals with target organ effects—chemicals that have an effect on specific organs, such as:
   - **a.** hepatotoxins producing liver damage
   - **b.** nephrotoxins producing kidney damage
   - **c.** neurotoxins producing nervous system damage or effects
   - **d.** agents acting on the blood or hematopoietic system decreasing hemoglobin function or depriving the body tissues of oxygen
   - **e.** agents irritating or damaging pulmonary tissue
   - **f.** reproductive toxins affecting reproductive capabilities including chromosomal damage (mutations) and those affecting the fetus (teratogenesis)
   - **g.** cutaneous hazards affecting the skin
   - **h.** eye hazards affecting the eyes or visual capacity

Occupational Safety and Health Administration (OSHA, 2015).

Chemical Exposure Measurements: Occupational Versus Emergency Values

Potential chemical exposure can be measured in several ways. Air sampling can be conducted, particularly in occupational settings. Air sampling results are compared with threshold limit values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH). These are guidelines which indicate safe levels of chemical exposures in the workplace. They are based on inhalation of a volume of chemical in the air expressed as parts per million (ppm) or milligrams of a chemical per cubic meter of air (mg/m^3). TLVs are not legal standards, but reflect a level of exposure that a typical healthy worker can experience during 8-hour workdays for 40-hour workweeks over a lifetime, without increased risk of disease or injury. The components of TLVs include time-weighted average (TWA) concentrations measuring chemical exposures in a worker's breathing zone for an entire workday. A TWA established by ACGIH is simply the average amount of exposure not to be exceeded in an 8-hour workday. Ceiling values are the levels never to be exceeded by anyone at any time during the workday. Short-term exposure limit (STEL) values are the levels of exposure never to be exceeded in a 15-minute period, even if the average TWA is below the recommended level. The STEL values are for contaminants with known short-term hazards. None of these measures are quantitative risk estimates and should not be used as acceptable levels for public exposure during an emergency. Communities are composed of people with diverse health and physiological status: children, elderly, those with chronic diseases, etc. Response activities and decisions must be based on the assumption that susceptible individuals could be injured by exposure levels that are below established TLVs. OSHA also uses permissible exposure limits (PELs). Although many of these limits are the same as those for TLVs, the OSHA PELs are regulatory limits and not just recommendations. There are over 500 PELs established in 29 CFR, 1910.1000, Limits for Air Contaminants, and Toxic and Hazardous Substances. In reality, the most prudent approach is to review the TLV

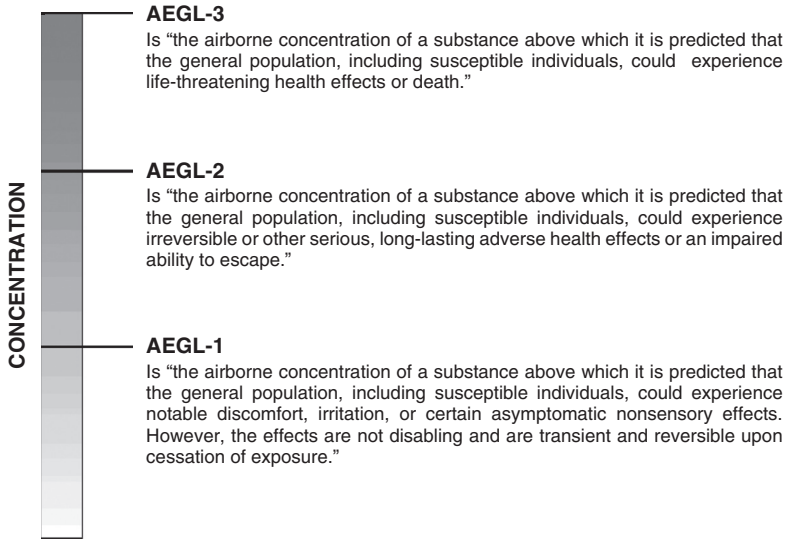

FIGURE 8-5 Acute exposure guideline levels (AEGLs) (NOAA, 2015).

and PEL and use whichever standard is most protective. Although these standards do not apply to allowable public exposures, they become important during the recovery process after a disaster. The importance of enforcing these recommendations and standards during recovery is highlighted by the continuing health problems being experienced by those who worked at Ground Zero in 2001 and 2002 following the collapse of the World Trade Center towers in New York City on 9/11.

Acute exposure guideline levels (AEGLs) are exposure descriptions that can assist in decision-making when a toxic chemical exposure potential exists for the general public (see Fig. 8-5). These recommendations are developed by the US Environmental Protection Agency (EPA) and the National Research Council's Committee on Toxicology (NRC-COT) through an open review and consensus process using a National Advisory Committee for AEGLs and stakeholders. AEGLs have been developed for hundreds of chemical agents, and others continue to be added. The AEGLs include recommended exposure limits at five exposure time intervals including 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. When these guideline levels are used with air modeling predictions, they can be very helpful in planning the best course of action to protect the public following an accidental industrial chemical release or a chemical terrorism attack (USACHPPM, 2003).

Above, using a chlorine release such as the one in Graniteville, South Carolina, is a breakdown of AEGLs Table 8-1. According to the data, most individuals in the population, including the majority of susceptible individuals, will not have significant health effects other than minor irritant effects if airborne concentrations are kept below 0.50 ppm. Given a scenario of a nursing home downwind from a chlorine release, if the residents are sheltering in place and the chlorine levels are predicted to be below 0.50 ppm, it may be best to plan on maintaining a shelter-in-place plan, as the chlorine levels outside are higher

Table 8-1 Graniteville, South Carolina 2005 Chlorine Release AEGLs

Time	AEGL-3 (ppm)	AEGL-2 (ppm)	AEGL-1 (ppm)
10 minutes	50	2.8	0.50
30 minutes	28	2.8	0.50
1 hour	20	2.0	0.50
4 hours	10	1.0	0.50
8 hours	7.1	0.71	0.50

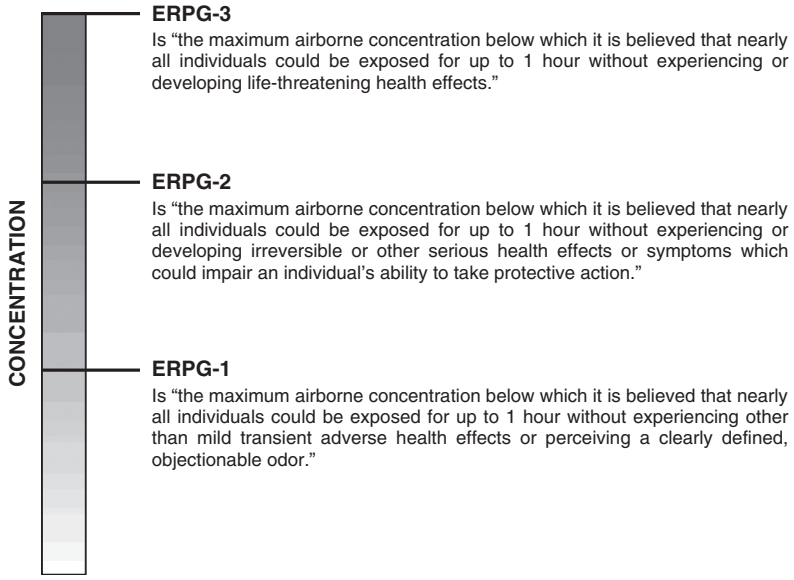

FIGURE 8-6 Emergency response planning guidelines (ERPGs) (NOAA, 2015).

than inside, and the levels inside are tolerable. However, if an evacuation plan is being considered, an informed decision can be made with estimated outcomes using the AEGLs.

Emergency response planning guidelines (ERPGs) are estimated concentrations also developed from published experimental data which apply to most individuals but do not address at-risk populations (see Fig. 8-6). There are just over 100 chemicals with established ERPGs. ERPGs are health-based guidelines for a single exposure for up to 1 hour and can be used to develop response plans and mitigation strategies (AIHA, 2006). The development of ERPGs is carried out by the American Industrial Hygiene Association (AIHA) ERP Committee. These recommendations should never be used for occupational exposure estimates or environmental exposures lasting more than 1 hour. They can be used for chemicals that do not have an established AEGL and when there is a chemical release with a short duration. ERPGs have a close correlation to AEGLs. However, AEGLs have lower values than ERPGs, as they consider at-risk populations. For example, the 1-hour AEGLs for chlorine compared with ERPGs displayed on Table 8-2.

Table 8-2 Comparison of Chlorine AEGLs and ERPGs

AEGL-3 = 20 ppm	ERPG-3 = 20 ppm
AEGL-2 = 2.0 ppm	ERPG-2 = 3.0 ppm
AEGL-1 = 0.50 ppm	ERPG-1 = 1.0 ppm

With expanding lists of chemical substances used in industry, many do not have an established AEGL or ERPG. For many chemicals without established values, a temporary emergency exposure limit (TEEL) can be used. As the name suggests, these are temporary guidelines used to estimate the potential impact on the health of the general public to different chemical concentrations. These values are established by the US Department of Energy Subcommittee on Consequence Assessment and Protective Actions. The way that TEELs are defined is the same as for ERPGs. In other words, a TEEL-1 is defined exactly the same way as an ERPG-1. However, this is a temporary recommendation calculated as the peak 15-minute TWA concentration.

AEGLs, ERPGs, and TEELs are all based on a chemical substance in the air. The values represent the expected physiological response of a population at a given exposure level. For immediate hazard assessments to chemical and contaminating events, an AEGL is the first choice. If there is not an AEGL available, an ERPG should be used. If there is no AEGL or ERPG value available, a TEEL may be used. Keep in mind that ERPGs and TEELs do not factor in at-risk populations such as the elderly, very young, etc. When carrying out recovery operations, occupational values should be used for those working in the area of potential exposure. It is recommended that safety officers of response organizations review the ACGIH TLVs and OSHA PELs and use whichever is most protective. There is one final value that is a last resort in preparedness planning if there are no available AEGL, ERPG, or TEEL values. If there are no public exposure guidelines available for a chemical substance, the final option is using 1/10 of the immediately dangerous to life and health (IDLH) value. Although the IDLH value is a workplace exposure limit, it is established by the National Institute for Occupational Safety and Health (NIOSH) and has been used in the past by many US agencies for hazard planning. Using the chlorine example once again, if the IDLH is 10 ppm, 1/10 is 1 ppm, which is the same value as the ERPG-1 level. Always keep in mind that this is not applicable to at-risk populations. The various exposure levels by guideline type are shown in Table 8-3.

Industrial Chemical Exposures and Contamination Incidents Versus Terrorism

In recent years, much attention has been focused on the increasing likelihood of chemical terrorism. The US Department of Homeland Security has developed 15 national planning scenarios which include four chemical contamination incidents. Two of these planning scenarios are industrial or transportation disaster threats, including a chlorine tank explosion and a toxic industrial chemical release. The other two chemical/contaminating scenarios are terrorist releases of nerve agents. In terms of specific federal, state, and local actions, is there a difference between preparing for an accidental chemical release and an intentional chemical attack? As far as the healthcare and public health challenges, the

Table 8-3 Summary of Occupational and Emergency Exposure Guidelines

Developers/Guideline	Use	Exposure Duration
ACGIH TLV and OSHA PEL	Occupational	Occupational exposure for an 8-hour day, 40 hours per week
ACGIH STEL	Occupational	Occupational exposure for a 15 minutes maximum time limit
NIOSH IDLH	Occupational	Highest concentration from which escape is possible with no adverse health effects within 30 minutes
EPA and NRC-COT AEGL	Public emergency	Three-tier emergency response recommendations for 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours
AIHA ERPG	Public emergency	Three-tier emergency response recommendations for 1 hour
FEMA, EPA, and DOT 1/10 IDLH	Public emergency	Highest concentration considered safe for most of the public for 30 minutes

differences are few. Although the role of law enforcement increases with an intentional incident, the health and safety issues are nearly identical. Any of these scenarios may require mass decontamination, mass care, medical countermeasure deployment, evacuation, and/or sheltering in place. Therefore, with a few exceptions, the preparedness activities for accidental and intentional chemical incidents are the same.

Chemical Terrorism

One noted difference between chemical terrorism and accidents is that some agents have no use in industry. Should an incident occur with any of these agents, it is reasonable to assume it is an intentional release. The most important examples of these are classic chemical warfare nerve and blister agents (see Table 8-4). Nerve agents include two primary categories, V-Series and G-series. The most recognized of the V-series agents is VX. The G agents include tabun (GA), sarin (GB), and soman (GD). The most widely used has been sarin. The "G" designation stands for German. Each of the agents in this series was developed in the 1930s and 1940s by Germany. Tabun was discovered first and called German agent A or "GA," sarin (GB) was second, and soman (GD) was third. The GC designation was skipped because it is already a widely used abbreviation for gonorrhea. A lesser known GF agent was also discovered (cyclohexyl methylphosphonofluoridate). Again, an abbreviation was skipped due to other uses; ie, GE is a common abbreviation for gastroesophageal (OPCW, 2008).

Blister agents or vesicants fall into one of four categories including lewisite (L), nitrogen mustard (HN), phosgene oxime (CX), and sulfur mustard (H). These nerve and blister agents were designed for the battlefield and serve no industrial purpose. However, there are still demilitarization activities underway around the world by nations who signed the Chemical Weapons Convention in 1997. This includes the deactivation, emptying, cleaning, and destruction of stockpiled chemical weapons including bombs, missiles, and land mines. As long as these activities are incomplete, there remains potential for an industrial

Table 8-4 CW Agent Group, Persistency, Rate of Action, Symptoms, and Treatment (OPCW, 2015)

CW Agent Group	Persistency	Rate of Action	Symptoms	Treatment
Choking Agents				
Chlorine (Cl)	Low	Variable	Eye irritation, airway irritation, stridor (high pitched airway sounds), chest tightness, sore throat, pulmonary edema	Decontaminate and offer supportive care. Priority is given to airway management and treatment of eye injuries.
Phosgene (PG)	Low	Delayed		
Diphosgene (DP)	Low	Delayed		
Chloropicrin (PS)	Low	Delayed		
Blister Agents				
Sulfur mustard (H, HD)	Very high	Delayed	Skin burns, burning, and swelling of the eyes, blindness, respiratory damage	Decontaminate and offer supportive care. No antidotes exist for most blister agents (ATSDR, 2002b). British anti-lewisite is effective against lewisite if given quickly (ATSDR, 2002d).
Nitrogen mustard (HN)	High	Delayed		
Phosgene oxime (CX)	Low	Immediate		
Lewisite (L)	High	Rapid		
Blood Agents				
Hydrogen cyanide (AC)	Low	Rapid	General weakness and confusion, headache, dizziness, shortness of breath. Exposed individuals with light skin may appear pink or red. This is due to the buildup of oxygen in the blood. Advanced symptoms include convulsions, low blood pressure, and respiratory failure.	Decontaminate and offer supportive care. Cyanide antidote is hydroxocobalamin (Cyanokit®). Arsine: no specific antidote (ATSDR, 2002a).
Cyanogen chloride (CK)	Low	Rapid		
Arsine (SA)	Low	Delayed		
Nerve Agents				
Tabun (GA)	High	Very rapid	Miosis (small pupils) is a hallmark of exposure. An easy way to remember common symptoms is the acronym "SLUDGE": Salivation, lacrimation, urination, diarrhea, gastroenteritis, and emesis. Advanced symptoms of higher exposures include seizures, muscle fasciculation, flaccid paralysis, apnea, and death.	Decontaminate and offer supportive care. Antidotes include atropine and pralidoxime chloride (2-PAM Cl) (ATSDR, 2002e).
Sarin (GB)	Low	Very rapid		
Soman (GD)	Moderate	Very rapid		
Cyclosarin (GE, GF)	Moderate	Very rapid		
VX	Very high	Rapid		

accident that results in the release of a nerve or blister agent. Outside this remote scenario, any discovery of a nerve or blister agent release is highly likely to be an act of terrorism.

Intentional and terrorist use of toxic industrial chemicals is also a possibility because of the ubiquitous use and transportation of chemicals such as chlorine, ammonia, and cyanide compounds. It is far more likely that a terrorist will attack an existing target of opportunity rather than establishing the necessary infrastructure for or acquisition of nerve and blistering agents.

Tokyo Subway Nerve Agent Attack by the Aum Shinrikyo Cult

The Aum Shinrikyo cult was founded by Shoko Ashara, who claimed to be "enlightened" after spending time meditating in the Himalayan Mountains. The cult he established in Japan espoused the belief that Ashara was destined to become a great ruler but in order to usher in his reign, an apocalyptic social collapse would be required. To that end, the cult pursued chemical and biological weapons (Kaplan and Marshall, 1996). After several unsuccessful attempts at using biological weapons and one somewhat effective chemical attack in Matsumoto City with seven casualties, the cult devised a plan to release sarin nerve agent in the Tokyo subway system. On March 20, 1995, cult members boarded five trains that were scheduled to converge at a busy central terminal. The sarin nerve agent was placed in plastic bags, wrapped in newspapers, and laid on the floor of each train. When it arrived at the station, the cult members ruptured their bags with the sharpened tip of an umbrella and exited the trains. The number of people affected was approximately 3800, with about 1000 requiring hospitalization and 12 fatalities (Olson, 1999).

There are many lessons to be learned from the attack on the Tokyo subway system. It sets a precedent and indicates the willingness of terrorists to inflict mass casualties using chemical weapons. It also highlights the difficulties in protecting the public from a diverse number of attack scenarios. The need for rapid diagnosis and treatment is crucial to limiting the impact of an attack on public health. This requires first responders and healthcare providers to understand how to recognize and react quickly to a variety of threats. It also requires a medical surge capacity which is exercised often enough to sustain effectiveness. In the case of sarin as well as several other chemical agents, there are specific antidotes which need to be maintained and readily available. Plans must be established and exercised to quickly deploy these resources during a crisis.

Chemical Accidents

Chemical accidents which occur at fixed facilities, as well as transportation accidents, can have a widespread impact on public health. Much can and has been done in the United States to prepare for each type of accident. There are mandates requiring fixed facilities to provide local and state authorities with details of the hazmats they produce, store, or use. This information allows for detailed advanced planning for how to best manage a hazmat release. Even though there are laws regulating the safe transportation of chemicals, transportation accidents pose unique challenges, given the wide array of chemicals being transported and the many response variables of how, when, and where an accident could occur.

A Virginia Army Guard Soldier from the Rocky Mount-based 229th Chemical Company transports an "injured" role player through the decontamination line during the Virginia Guard CERFP external evaluation April 27, 2013. Virginia Guard Public Affairs Photo by Sgt. 1st Class A.J. Coyne.

Morbidity and Mortality of US Hazardous Materials (Hazmat) Accidents: A 10-Year Summary (1999–2007)

- Total hazmat accidents = 169,076
  - highway = 146,584 (86.7%)
  - air = 13,563 (5.1%)
  - rail = 8652 (2.1%)
  - water = 277 (<1%)
- Total hazmat injuries = 2824
  - highway = 1546 (54.7%)
  - rail = 1104 (39.1%)
  - air = 154 (5.5%)
  - water = 20 (<1%)

- Total fatalities = 141
  - highway = 124 (88%)
  - rail = 17 (12%)

In the United States from 2006 to 2014, there were over 150,000 hazmat accidents resulting in over 90 fatalities. Over half (76,719 or 51%) occurred when material was being unloaded, 36,388 (24%) while in transit, 28,911 (19%) while being loaded, and 8070 (6%) while in transit storage. However, 76 of the 91 fatalities (84%) occurred in association with transit accidents (DOT, 2015). During a 10-year period, 1998–2007, there were over 169,000 transportation accidents in the United States involving hazmats. Over 86% of these accidents occurred on highways, compared with only 8% by air, 5% by rail, and less than 1% on water. Among the over 2800 incidents which resulted in injuries and illnesses, 55% were from highway accidents and 39% from rail accidents. Rail accidents occur far less frequently, but when they do occur, they have a much larger footprint and therefore, a greater impact on public health per incident, largely because of the quantity and type of substances transported. The vast majority of the 141 hazmat-related fatalities during this period are attributed to highway incidents. During this timeframe, highway accidents accounted for 88% of hazmat fatalities, with 12% due to rail accidents (PHMSA, 2008).

Most Common Hazardous Materials Releases (Binder, 1989)

1. natural gas
2. chlorine
3. gasoline
4. sulfuric acid
5. hydrochloric acid
6. ammonia
7. sodium hydroxide
8. diesel oil
9. corrosive liquids
10. nitric acid/phosphoric acid

Given the massive quantities of hazardous industrial chemicals transported and used each day, the total number of individuals who ever become injured, ill, or suffer a lethal exposure from a chemical accident is relatively low. Chemical accidents are preventable, and with the knowledge, tools, and regulations existing in the United States today, these incidents should be rare and easily containable.

Prevention

Preparing for the full range of possible chemical emergencies requires action at every level of government as well as in every home. Federal, state, and local governments all play a role in developing and implementing measures to reduce the likelihood of chemical accidents. The preparedness activities of emergency managers, planners, and others are important, but cannot reach into every home across communities where chemical hazards exist. It is also not enough to simply follow labeling instructions for household chemical use. The ways that household chemicals are stored, as well as where chemicals may be dispersed when displaced by disasters such as earthquakes or hurricanes, can also pose significant chemical hazards.

Community Prevention Activities

To reduce the inherent public health risks of having chemicals throughout industry crossing the network of highways (see Fig. 8-7), railways, and waterways, a variety of local and state agency activities are necessary. In the United States, public agency activities begin with regulations such as the Emergency Planning and Community Right-to-Know Act (EPCRA), Superfund Amendments and Reauthorization Act of 1986, and chemicals listed under Section 112(r) of the Clean Air Act. The EPA has compiled the "Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA) and Section 112(r) of the Clean Air Act," also referred to as the "List of Lists." This document lists the chemicals required to be reported by industry to local and state officials (EPA, 2001). Industry reports the quantities of chemicals on the list to state and local planners. The planners use this industry-reported information to determine worst case

FIGURE 8-7 Overturned tanker truck. *US Department of Transportation.*

chemical release scenarios, develop plans, and carry out training and exercises to better prepare for the most likely scenarios in their regions.

Local Emergency Planning Committees (LEPCs) were established by the EPCRA to carry out community-level preparedness activities. The LEPC is required to include local first responders, emergency management, public health, environmental, transportation, industry officials, and the local media. When a local industrial operation reports the presence of a notifiable quantity of potentially hazardous chemicals to the LEPC, the members develop an emergency response plan specific to the threat. The response plan is reviewed and updated as needed, at least annually. The information and plans compiled are open to the community. Each state maintains a state emergency response commission that appoints members and establishes jurisdictional areas for each LEPC. Should there be an accidental release of a hazardous chemical, the industry responsible for the release is required to report the details, including estimates of what was released, what the potential public health impact may be, and what community precautions should be instituted. This reporting process was instituted in the United States shortly after the 1984 disaster in Bhopal, India, where a Union Carbide facility experienced an accidental release of methyl isocyanate that resulted in thousands of deaths and tens of thousands of long-term injuries.

The Worst Industrial Chemical Accident in History: Bhopal, India

In the early morning hours of December 3, 1984, an accidental release occurred at a Union Carbide facility in Bhopal, India. Tons of methyl isocyanate leaked throughout the morning, resulting in over 3800 deaths and thousands more who became chronically ill, which continues decades later to contribute to premature death among those exposed. The facility was manufacturing pesticides and struggling to stay in business. Local officials knew there were safety issues, but did not want to do anything to increase the financial burden on the facility and risk losing a large employer in their community (Shrivastava, 1987). A massive malfunction at the facility caused the release of methyl isocyanate, and thousands of mostly impoverished local residents began collapsing in the streets. There was a lack of community awareness of what the facility produced, and a lack of community preparedness, including at local healthcare facilities. Local hospitals did not know what chemical or chemicals had been released, and had no idea how to treat those exposed who managed to make it to the hospital (Fortun, 2001). Debates raged for years concerning how many people were actually exposed and how many died. The true numbers may never be fully known. A legal settlement was reached several years after the accident, and payments were made to survivors and their families. Compensation was awarded to over 500,000 people who claimed they were injured, and to over 15,000 surviving family members of those who perished. The total settlement was $470 million paid by Union Carbide to the government of India, which in turn paid out an average of $2200 to each survivor. Thousands of Bhopal residents require daily medical care decades after the release (Kumar, 2004).

Many difficult and important lessons were learned from the Bhopal tragedy. There has never been an event in modern history with a greater impact on industrial safety. The lessons include the need for communities to know in advance what potential hazards are introduced through their local industry. In the United States, the Emergency Planning and Community Right-to-Know

Continued

The Worst Industrial Chemical Accident in History: Bhopal, India—cont'd

Act (EPCRA) of 1986 was the regulatory response. The challenge is to find the balance between informing the public and providing too much information to those who may use it to formulate a crude chemical attack by targeting facilities with toxic materials. Although the EPCRA legislation led to the establishment of State and Local Emergency Planning Committees in the United States, similar requirements are needed internationally in order to prevent companies from building dangerous operations in the highly populated areas of nations that have lax regulation. Local governments must exercise caution in determining where facilities with large quantities of dangerous materials are allowed to be sited. Prevention activities in every nation need to begin with safety legislation and facility design. In addition, risk reduction activities need to be required in all industrial facilities with large quantities of hazardous chemicals (Bertazzi, 1999).

Reducing Vulnerability in Critical Buildings

High-risk facilities such as hospitals, government buildings, and large public venues should have a comprehensive vulnerability assessment of the air-handling unit (AHU) completed in order to ensure that a detailed risk reduction plan is developed and implemented. For other buildings, there are several simple steps to be taken to reduce the risks associated with chemicals accidentally or intentionally being introduced into the AHU. One of the most important vulnerabilities is the positioning of the outdoor air intakes. Many air intakes are located on ground level in easily accessible areas. This poses two problems. If the air intake is easy to access, the building is more susceptible to an attack. A person with a simple hand sprayer can easily deliver material into the air-handling system, which could affect occupants. Secondly, many toxic chemicals are heavier than air and stay close to the ground. Air intakes positioned near the ground are more likely to draw in chemicals from an industrial release or transportation accident. To reduce these threats, several steps can be taken. Physical security of the outdoor air intake, as well as limiting access to the building maintenance areas, is the first step. If mechanically and financially feasible, it is better to relocate low-lying outdoor air intake vents to less-accessible and more-elevated areas. There are also ways to build intake extensions which draw the air in at a higher level without disturbing the function of the building's AHU (see Fig. 8-8). An intake elevated above 12 feet (3.7 m) with a 45 degree sloped top will be out of reach for tampering. This elevated air intake will also limit the risk of drawing in heavier-than-air toxic chemicals (NIOSH, 2002). It is also important for building managers to develop procedures for quickly shutting down the AHU when there is an emergency and to have a plan for managing building occupants safely if the need arises to shelter in place.

Home Prevention Activities

In the home, many household products are accumulated which, individually or combined, can pose a risk to residents. These risks can result from improper usage or from

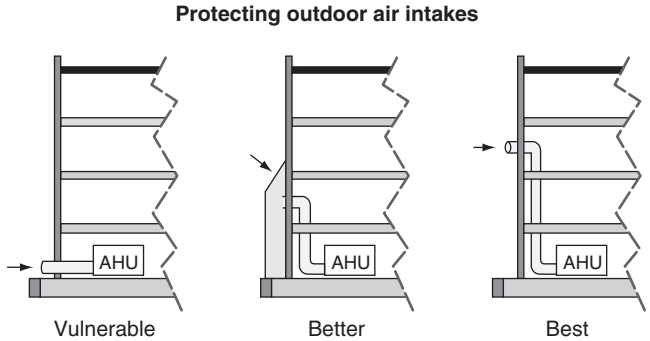

FIGURE 8-8 Reducing the vulnerability of air-handling units (AHUs) by repositioning the outdoor air intake (NIOSH, 2002).

the inadvertent mixing of chemicals resulting from other disasters. Following any major disruption of a home, an assessment must be made of the chemical substances stored inside. Harmful concentrations of the by-products of mixed chemicals can pose a risk to those entering buildings after a disaster. Harmful chemicals can be found in household products such as:

- paints and solvents
- indoor and outdoor pesticides
- automotive fluids
- kitchen and bathroom cleaners
- health and beauty products
- lawn and garden products
- swimming pool supplies
- barbecue products
- mercury thermometers

It is far more likely that most people will experience a chemical emergency in the home than from industrial or transportation accidents. Chemical materials should be properly disposed of, and no needless chemical materials should be stored in the home. Hazardous chemicals should not be stored in unlabeled containers. Shelves where hazardous chemicals are stored should be mounted securely and labeled. Incompatible chemical products should be identified and segregated. A metal storage cabinet is ideal for storing hazardous chemicals.

Immediate Actions

There are a variety of ways a chemical release or contamination incident can be detected. Clues vary and depend upon the chemical. A strong odor can be detected in the environment or emanating from exposed individuals. Common symptoms can be shared among the exposed. Chemical exposure symptoms include watery eyes or nose, burning of the

eyes or skin, difficulty breathing or tightness in the chest, nausea, vomiting, headache, or a number of other symptoms which comprise various chemical exposure syndromes (CDC, 2003). With some chemical exposures, these clues can be easy to miss in individual patients. The defining clues can be observed in a cluster of patients with similar symptoms. The level of suspicion should be raised when multiple patients from a single location suddenly develop the same symptoms. If this is the case, it is unlikely to be a biological event, intentional or natural. There can also be clues in the environment such as dead insects, birds, or other animals. Over time, plants can die or experience changes in appearance or color. Although a chemical release can have large-scale dramatic effects which are impossible to miss, some chemical releases can have a much more subtle progression.

Indicators of a Chemical Release

1. Syndromic
   - **a.** dermatological
   - **b.** respiratory
   - **c.** neurological
   - **d.** gastrointestinal
2. Epidemiological
   - **a.** an abnormal number of patients with similar symptoms
   - **b.** a cluster of illnesses among patients with something in common, such as a shared food or water source
   - **c.** a rapid onset of symptoms among patients with a common exposure
   - **d.** a specific pattern of symptoms or a syndrome suggesting a chemical exposure
3. Environmental
   - **a.** odors
   - **b.** unusual plume, cloud, vapor, or droplets
   - **c.** rapid onset of illness or death among wild or domestic animals
   - **d.** changes in the appearance or color of plants.

The clues indicating that a release is occurring depend upon the mechanism of release. There may be obvious signs from an industrial facility or transportation accident including fire, explosion, or a plume release. If a spill has occurred, there may be little evidence of a release for those who do not directly observe the release/spill at the source. Vapors emitted from a spill may be invisible, have no odor, and travel a substantial distance, making it difficult for those downwind to recognize it. If a home or other building is structurally damaged by disasters such as floods, earthquakes, or hurricanes, there may also be spilling and mixing of household chemicals that pose a risk to those entering the structure. Chemical contamination can also be intentionally introduced into the environment, food, water, or over-the-counter pharmaceuticals.

Ninth Ward, New Orleans, Louisiana, September 16, 2005. This neighborhood remains flooded 2 weeks after Hurricane Katrina. The foul-smelling floodwater is contaminated with petrochemicals, household chemicals, and biological hazards. *Federal Emergency Management Agency photo by Marvin Nauman.*

Individual Response

If a major chemical release occurs, notification may come directly from first responders. First responders will sometimes go door to door, drive through the affected community using loudspeakers, contact residents by phone, use television and radio warnings, or use a combination of any or all these approaches to notify residents. Depending on the type and quantity of chemical released, it can be more hazardous to evacuate than to simply stay inside until the chemical release dissipates. Response officials assess the circumstances and decide whether it is best for the surrounding community to evacuate or shelter in place. They will then provide information to the public on who, what, where, when, why, and how:

- populations at risk of exposure
- characteristics of the hazards
- where the public should or should not go for information, healthcare, or evacuation
- when actions should be taken
- why the recommendations are important
- how to carry out recommendations such as sheltering in place

Residents sheltering in place should immediately bring all family members and pets inside. Heating, ventilation, and air-conditioning systems should be turned off. All openings including windows, doors, and fireplace dampers should be closed. No building is airtight. To minimize what can slip through the cracks and expose occupants, plastic, and tape may be used to seal windows, doors, vents, and outlets. Because most hazardous

chemicals are heavier than air, everyone should take shelter on the highest floor of the building in a room with the fewest windows. Damp towels may be placed under the door of the room as well. Occupants should shelter in place until an "all clear" message is announced. The "all clear" message is typically made within a couple hours. Otherwise, evacuation would be recommended (FEMA, 2006).

Residents asked to evacuate during a chemical emergency should pick up their disaster kit and immediately follow the instructions given. Advice on which routes to follow or avoid should be included in an evacuation order. If there is time, all windows, doors, and vents in the home should be closed and taped shut. Also, evacuees should be reminded that if there are at-risk neighbors nearby, assistance should be offered as long as it does not put more people at more risk. Those who have infants or who are disabled or elderly may not be able to evacuate without support. As people drive out of areas near a chemical release, vehicle vents, air conditioning, and heating systems should be turned off, and vehicle windows should remain closed until clear of the hazards. Instructions include reminding evacuees to take essential items such as medications, personal care items, and a change of clothes. Most shelters will only provide minimal support including a cot, blanket, and meal (ARC, 1994). All other personal necessities should be brought with the evacuee.

Healthcare Response

The medical responses for many different chemical release or contamination incidents are similar. The primary challenges are diagnosis and decontamination of the exposed. Both diagnosis and decontamination posed enormous challenges in Tokyo following the 1995 sarin release in the subway system. For every person seeking care, there were about five additional people who sought care even though it was not needed. The "worried well" can complicate the health and medical response to a chemical release. Unlike traumatic injuries where triage is conducted based on the initial presentation of a patient, chemical exposure is much more difficult to assess. Although some chemical exposures will have obvious acute effects, many exposures have delayed or chronic effects not easy to evaluate during the triage process. It will be challenging to distinguish the worried well from those with delayed effects. As a result, it is necessary to establish a case definition and use case classifications such as "suspected," "probable," and "confirmed." Establishing the case definition can be complicated and further convoluted by exposure to more than one chemical substance (CDC, 2005a). Healthcare providers must work closely with poison control centers and local public health agencies (LPHAs) in establishing the case definition and carrying out proper requests for resources and case reporting.

When patients from a suspected chemical incident begin to arrive, they should be held outside until the emergency department is prepared (CDC, 2013b). Healthcare staff should don personal protective equipment and ensure that screening for contamination is conducted and appropriate patient decontamination accomplished before patient entry is allowed. Patient decontamination was also a challenge after the sarin release in Tokyo. Many of the exposed patients entered the emergency departments and spread

contamination in the facility by "off-gassing," exposing healthcare providers as well. If patients are ambulatory, they should remove their own clothing and do as much self-decontamination as possible. If they are not able to do so, hospital staff may be required to cut away clothing articles and conduct decontamination activities for the patient. There are several decontamination options available. The two primary methods to decontaminate a chemically exposed patient are physical removal and chemical deactivation. Profuse amounts of water or dry absorbent materials can be used for removal (USAMRICD, 2000). Chemical deactivation includes hydrolysis and oxidation. Hydrolysis options include mildly acidic solutions, alkaline solutions, or soap and water. Oxidizing options include chlorine or peroxide-based solutions. Patient decontamination processes need to be trained and exercised frequently enough to ensure that all staff on all shifts can carry it out rapidly and effectively (see Fig. 8-9).

For most chemical disasters, the primary medical goals are patient evacuation, decontamination, and supportive care. However, unique antidotes are required for nerve and cyanide agents (ATSDR, 2002c). Nerve agent antidotes include atropine and 2-PAM chloride. The biggest challenge that healthcare providers may encounter is acquiring enough antidotes for a mass casualty event. The CDC has been working with state and local public health and healthcare organizations to field "Chempacks." This program places dozens of containers storing nerve agent antidote at secure locations in each state so they are available quickly during a crisis at the community level. When a community is threatened by a nerve agent release and lives are at risk, hospitals may utilize the resources from Chempacks they host and request more resources from other hosting organizations if they exceed their capacity. However, the Chempacks only provide antidote for nerve agents. Another

FIGURE 8-9 US Air Force healthcare providers at Andersen Air Force Base receiving training on a new in-place patient decontamination system. *US Air Force photo by Staff Sgt. Vanessa Valentine.*

agent requiring unique drug therapy is cyanide. Large amounts of cyanide compounds are used in industry, and there is the possibility of being exposed to cyanide by-products during structural fires. There are currently two methods available to treat cyanide poisoning. The several decades' old method is a multistep process using amyl nitrite perles, sodium nitrite IV, and sodium thiosulfate IV. Another treatment option, approved for use in the United States by the Food and Drug Administration in 2006, is hydroxocobalamin. This is a precursor of vitamin B12 which has been used with great success for smoke inhalation patients in Europe (Davis, 2006). The availability of cyanide treatment is diminishing nationally, and there is a lack of antidote surge capacity.

Public Health Response

Much of the surge capacity needed during a chemical disaster can be facilitated through public health agencies. In the United States, accessing stockpiles of antidotes is coordinated through state and local public health agencies, and if more medical staffing is needed, additional healthcare professionals may be requested through public health agencies as well. LPHAs can assist in coordinating local healthcare or shelter volunteers by sending formal requests to the state for additional state or federal resources. Depending on the nature of a chemical release, there may not be a clear emergency scene or enough of an immediate patient surge to indicate that anything unusual has occurred. There also may not be any immediate human health findings. Animal or fish kills may be the first indicators of a toxic release. Public health agencies have ties to environmental, emergency management, and agricultural agencies which can provide situational awareness and provide the first clues for alarm. Most public health agencies have the legal authority to close natural areas as well as buildings in order to protect public health and safety. Chemical exposures may also be detected or characterized through public health surveillance or epidemiological investigation. Surveillance activities are the key to long-term follow-up for residual effects. Public health also develops health-risk communication messages for the public in times of crisis and shares state-of-the-art diagnosis and treatment information with healthcare organizations and providers. Typically, environmental chemical samples are not taken or handled by public health professionals. However, clinical specimens are routinely obtained and handled by public health professionals. The CDC and many state public health laboratories have established the capacity to analyze blood, serum, and urine specimens to detect and measure exposures to nerve agents, blister agents, ricin, cyanide, and others. If the chemical release under investigation appears to be intentional, public health officials will work closely with local, state, and federal law enforcement officials. All clinical and epidemiological data can be used as evidence in a future criminal case.

There are unique chemical risks associated with most nonchemical disasters as well. When a structure is damaged by a flood, hurricane, tornado, or earthquake, chemical substances are often spilled and mixed with other chemicals. This can pose substantial risks to first responders conducting search and rescue or damage assessment operations as well as to individuals returning to their properties. Environmental health professionals play a key

role in assessing the range of chemical health risks produced by disasters and providing recommendations for chemical risk reduction.

A hazardous materials response team practices life-saving rescue methods. Photo courtesy of the Federal Emergency Management Agency.

Recovery Actions

Once a chemical emergency is over, residents of the affected area should not reenter the area until local authorities announce that it is safe for them to return. Frequently the health risk assessments required to determine reentry safety are conducted by public health, either alone or in conjunction with environmental teams. When building owners and residents return to the area, they should thoroughly ventilate the structure by opening all windows and turning on air-handling systems. If at any point they begin to detect the presence or feel the effects of a chemical exposure, occupants should immediately leave the facility and contact authorities. Although structures offer some protection from chemicals outside and can be used to shelter in place, once the hazard clears from the outdoor environment there is sometimes a residual low-level buildup of chemical vapors inside. Anyone coming into contact with suspicious liquid or solid material in or near the structure should be instructed to take quick action to decontaminate. Contaminated clothes should be placed in sealed bags or containers. Individuals should decontaminate themselves by taking showers, seek medical attention immediately for any symptoms, notify authorities of the material, and advise others in the surrounding area. When cleaning up a household chemical spill, individuals should use personal protective equipment recommended by the product labeling, and place the rags, paper towels, or other cleanup debris in a plastic bag for disposal (see Fig. 8-10).

A variety of other safety issues must be considered. If the disaster is not a chemical incident but one which causes structural damage, it is possible that hazardous chemicals have been spilled and possibly mixed with others to create a potentially toxic mixture. If there are widespread issues such as this, public agencies may establish drop-off locations to bring hazmats in for proper disposal. Public messaging should ensure that all important local emergency numbers are readily available, including the Poison Control

FIGURE 8-10 The Environmental Protection Agency has set up a hazardous waste material collection site for the disposal of toxic and otherwise hazardous materials. The site is located in the center of Cameron, Louisiana, which was severely affected by Hurricane Rita. *Federal Emergency Management Agency photo by Robert Kaufmann.*

number. The US National Poison Control Number is 800-222-1222. If there is structural damage, even though there may be no apparent odors or obvious evidence of a flammable risk, a flame can result in a fire or explosion. If natural gas is present, even a small spark generated by a flashlight could cause an explosion. If gas is smelled, people should immediately exit the building and contact authorities. The call should not be made inside the house but upwind of and outside the house.

If a power outage is experienced when residents return to their homes, some residents will use generator power. The use of gas-powered generators introduces the risk of carbon monoxide (CO) poisoning. CO poisoning is one of the most common causes of death during recovery operations from major disasters. Running a generator or vehicle in a garage or other unventilated area can quickly produce enough carbon monoxide to result in illness or death. CO is colorless and odorless, making it very difficult to detect without a CO detector. Burning in a fireplace with a blocked flue or using charcoal grills or other fuel burning appliances inside can also generate CO (UL, 2008).

At-Risk Populations

Chemical releases or contamination incidents have a dramatically different impact on at-risk populations throughout an impacted community. Children have more respirations per minute than adults and have breathing zones closer to the ground. Sarin, chlorine, or other toxic chemicals with greater vapor density will be more concentrated in a lower breathing zone; therefore, children will take more respirations in a more highly concentrated area of the release (Bearer, 1995). Infants have more permeable skin and a greater

surface-to-mass ratio, making them more vulnerable to dermal exposures (Slater and Trunkey, 1997). The greater surface-to-mass ratio of the infant can also result in rapid heat loss, placing infants at greater risk for hypothermia during decontamination operations. Another decontamination challenge is the handling of infants by workers in protective clothing. Protective gear limits vision, mobility, and dexterity, making it difficult to effectively handle small, frequently wet, and squirming patients (Tucker, 1997). Physiologically, children are not "small adults," and respond differently to chemical exposures (Landrigan et al., 1998). For example, a newborn child is up to 164 times more susceptible to organophosphates and 65 times more sensitive to the insecticide Diazinon (Furlong et al., 2006). Between the ages of 1 and 6 years, a child's rapid growth can be affected by chemical exposures, resulting in improper development.

Infants are particularly susceptible to chemical exposures. *Photo courtesy of the Centers for Disease Control and Prevention.*

According to the 2010 US Census Bureau, about 19% of the US population is disabled. Over 56 million people have some sensory, physical, mental, self-care, or employment disability (USCB, 2012). Each of these groups poses unique challenges to chemical preparedness and response. Some disabled individuals cannot understand instructions during a crisis, and others may not be capable of following the instructions given. Local emergency planners need to work closely with disability advocacy groups to better characterize the at-risk populations in their community and develop disability-competent messaging and message delivery systems. Planning includes consideration of personal care equipment, mobility aids, adaptive feeding devices, service animals, specially equipped vehicles, and medical equipment requiring power. During a release or contamination incident, evacuation of at-risk populations may require specialized services, and decontamination of the disabled and their equipment may pose unique challenges.

There are also distinct public health needs in pregnant and nursing mothers during a chemical release or contamination incident. Chemical exposures can permanently and disproportionally damage developing fetal organs. Priority evacuation, treatment,

and decontamination should be offered to pregnant victims whenever possible. Following a chemical release, mothers with newborns can unknowingly increase the potential exposure of their babies to certain chemicals through breastfeeding. A variety of environmental chemicals have been found in human breast milk including mercury and methyl mercury, lead, cadmium, polychlorinated biphenyl (PCBs), chlorinated dibenzo-*p*-dioxin (CDDs), and many others (ATSDR, 2004). Following any chemical incident, recommendations should include a description of any risks associated with exposed women nursing their babies, and accommodations may need to be made to supply formula and clean water.

Summary

As threats of chemical terrorism persist and as hazardous industrial chemicals continue to be produced, stored, and transported across highways, railways, and waterways, the need to enhance chemical emergency preparedness remains crucial. The differences between preparing for intentional and for accidental chemical releases are few for those with public health and healthcare responsibilities. Unique public health challenges resulting from chemical exposures and contamination incidents span across every facet of the emergency management process. Exposures are mitigated by continual industrial process safety, reporting, and enhanced security. There are also important mitigation steps that must begin in each home by reducing the hazardous chemicals, organizing a home preparedness kit, making a plan, and following the instructions of officials. Consistent, uniform labeling and nomenclature continues to develop, and emergency exposure standards continue to be refined through lessons-learned exercises and responses. The focus of these activities must cover the full lifecycle of chemical products from industry to homes. The response to major contamination incidents may include rapid diagnosis and treatment, mass care, mass fatality management, medical countermeasure deployment, and long-term plans to monitor exposed survivors. Much progress has been made in these areas in recent years, but much more is needed. Sustained improvements require public–private partnerships. There is little that public agencies can do to enhance their response and recovery activities without the cooperation of industry and citizens before, during, and after a disaster.

Websites

Agency for Toxic Substance and Disease Registry. www.atsdr.cdc.gov.

Agency for Toxic Substance and Disease Registry. Medical Management Guidelines (MMGs) for Acute Chemical Exposures. http://www.atsdr.cdc.gov/MMG/index.asp.

American Industrial Hygiene Association. Emergency Response Planning Guidelines. https://www.aiha.org/get-involved/AIHAGuidelineFoundation/EmergencyResponsePlanningGuidelines/Pages/default.aspx.

American Red Cross Chemical Emergency Preparedness. http://www.redcross.org/prepare/disaster/chemical-emergency.

Centers for Disease Control and Prevention. Case Definitions for Chemical Poisoning. http://www.cdc.gov/mmwr/PDF/rr/rr5401.pdf.

Centers for Disease Control and Prevention. Emergency Preparedness & Response Chemical Emergencies. http://www.bt.cdc.gov/chemical/.

Centers for Disease Control and Prevention. Public Health Emergency Response Guide for State, Local, and Tribal Public Health Directors. www.bt.cdc.gov/planning/pdf/cdcresponseguide.pdf.

Department of Energy, Office of Emergency Management and Policy Protective Action Criteria for Chemicals – Including AEGLs, ERPGs, & TEELs. http://orise.orau.gov/emi/scapa/chem-pacs-teels/.

Department of Energy. Subcommittee on Consequence Assessment and Protective Actions (SCAPA). www.orise.orau.gov/emi/scapa/default.htm.

Department of Transportation. Pipeline and Hazardous Materials Safety Administration, Library. http://phmsa.dot.gov/hazmat/library.

Department of Transportation. Pipeline and Hazardous Materials Safety Administration, Hazmat Safety Community. http://phmsa.dot.gov/hazmat.

Environmental Protection Agency. Acute Exposure Guideline Levels. www.epa.gov/oppt/aegl/.

Environmental Protection Agency. Computer-aided Management of Emergency Operations (CAMEO) Program. www.epa.gov/emergencies/content/cameo/index.htm.

Environmental Protection Agency. Pesticide A–Z Index. www.epa.gov/pesticides/a-z/index.htm.

Food and Drug Administration. Food Defense. http://www.fda.gov/food/fooddefense/.

National Institute for Occupational Safety and Health (NIOSH). Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks. http://www.cdc.gov/niosh/docs/2002-139/.

National Institute for Occupational Safety and Health (NIOSH). Emergency Preparedness for Business. http://www.cdc.gov/niosh/topics/emres/business.html.

National Institute for Occupational Safety and Health (NIOSH). Pocket Guide to Chemical Hazards. http://www.cdc.gov/niosh/npg/default.html.

National Library of Medicine. Toxicological Data Network-toxnet. http://toxnet.nlm.nih.gov/.

National Pesticide Information Center. http://npic.orst.edu/.

United Nations. Globally Harmonized System of Classification and Labeling of Chemicals (GHS) Program: www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html.

References

Agency for Toxic Substances and Disease Registry (ATSDR), 2002a. Managing Hazardous Materials Incidents, vol. 3: Medical Management Guidelines for Arsine. U.S. Department of Health and Human Services, Atlanta, GA. Available at: www.atsdr.cdc.gov/MHMI/mmg169.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR), 2002b. Managing Hazardous Materials Incidents, vol. 3: Medical Management Guidelines for Blister Agents: Nitrogen Mustard (HN-1, HN-2, and HN-3). U.S. Department of Health and Human Services, Atlanta, GA. Available at: www.atsdr.cdc.gov/MHMI/mmg164.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR), 2002c. Managing Hazardous Materials Incidents, vol 3: Medical Management Guidelines for Hydrogen Cyanide. U.S. Department of Health and Human Services, Atlanta, GA. Available at: www.atsdr.cdc.gov/MHMI/mmg8.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR), 2002d. Managing Hazardous Materials Incidents, vol. 3: Medical Management Guidelines for Lewisite and Mustard Lewisite Mixture. U.S. Department of Health and Human Services, Atlanta, GA. www.atsdr.cdc.gov/mhmi/mmg163.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR), 2002e. Managing Hazardous Materials Incidents, vol. 3: Medical Management Guidelines for Nerve Agents: Tabun (GA), Sarin (GB), Soman (GD), and VX. U.S. Department of Health and Human Services, Atlanta, GA. www.atsdr.cdc.gov/MHMI/mmg166.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR), 2004. Interaction Profile for Persistent Chemicals Found in Breast Milk, (Chlorinated Dibenzo-p-dioxins, Hexachlorobenzene, p,p′-DDE, Methylmercury, and Polychlorinated Biphenyls). U.S. Department of Health and Human Services, Public Health Service. May, 2004. Available at: http://www.atsdr.cdc.gov/interactionprofiles/IP-breastmilk/ip03.pdf.

American Industrial Hygiene Association (AIHA), 2006. ERP Committee Procedures and Responsibilities. AIHA, Fairfax, VA. Available at: https://www.aiha.org/get-involved/AIHAGuidelineFoundation/EmergencyResponsePlanningGuidelines/Documents/ERP-SOPs2006.pdf.

American Red Cross (ARC), 1994. Your Guide to Home Chemical Safety and Emergency Procedures. www.redcross.org/static/file_cont157_lang0_67.pdf.

Bachman, E.G., July 31, 2013. Globally harmonized system: what is it. Fire Eng. Available at: http://www.fireengineering.com/articles/2013/07/globally-harmonized-system-what-is-it.html.

Bearer, C.F., 1995. How are children different from adults? Environ. Health Perspect. 103, 7–12.

Bertazzi, P.A., 1999. Future prevention and handling of environmental accidents. Scand. J. Work Environ. Health 25, 580–588.

Binder, S., 1989. Death, injuries, and evacuations from acute hazardous materials releases. Am. J. Public Health. 79 (8), 1042–1044. www.ajph.org/cgi/reprint/79/8/1042.pdf.

Cave, D., Fadam, A., February 21, 2007. Iraqi Militants Use Chlorine in 3 Bombings. The New York Times. www.nytimes.com/2007/02/21/world/middleeast/21cnd-baghdad.html.

Centers for Disease Control and Prevention (CDC), 2003. Recognition of illness associated with exposure to chemical agents-United States, 2003. MMWR. 52 (39), 938–940. www.cdc.gov/mmwr/preview/mmwrhtml/mm5239a3.htm#tab.

Centers for Disease Control and Prevention (CDC), 2005a. Case definitions for chemical poisoning. MMWR. 54 (RR01), 1–24. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5401a1.htm.

Centers for Disease Control and Prevention (CDC), 2005b. Public health consequences from hazardous substances acutely -released during rail transit—South Carolina, 2005; selected states, 1999–2004. MMWR. 54 (3), 64–67. www.cdc.gov/mmwr/preview/mmwrhtml/mm5403a2.htm.

Centers for Disease Control and Prevention (CDC), 2013a. Emergency Preparedness and Response, Chemical Categories. Available at: http://www.bt.cdc.gov/agent/agentlistchem-category.asp#vomiting.

Centers for Disease Control and Prevention (CDC), 2013b. Chemical Weapons Elimination, Emergency Room Procedures in Chemical Hazard Emergencies: A Job Aid. Available at: www.cdc.gov/nceh/demil/articles/initialtreat.htm.

Davis, R., December 28, 2006. FDA Gives Green Light to Cyanide Treatment. USA Today. www.usatoday.com/news/health/2006-12-27-cyanide_x.htm.

Department of Transportation (DOT), 2015. Data.gov. Hazmat Yearly Incident Summary Reports: Data Mining Tool. Available at: https://catalog.data.gov/dataset/hazmat-yearly-incident-summary-reports-data-mining-tool.

Environmental Protection Agency (EPA), 2005. Norfolk Southern Graniteville Derailment. www.epa.gov/region4/graniteville/index.htm.

Everitt, R., 2004. Falling Stars: Air Crashes that Filled Rock and Roll Heaven. Harbor House, Augusta, GA.

Federal Emergency Management Agency (FEMA), 2006. What to Do during a Hazardous Materials Incident. http://www.ready.gov/hazardous-materials-incidents.

Fortun, K., 2001. Advocacy after Bhopal. University of Chicago Press, Chicago, IL.

Furlong, C.E., Holland, N., Richter, R.J., et al., 2006. PON1 status of farmworker mothers and children as a -predictor of organophosphate sensitivity. Pharmacogenet. Genomics 16, 183–190.

Hart, A., Wald, M.L., January 8, 2005. Cloud Rising from Train Wreck, Then Death and a Ghost Town. The New York Times. www.nytimes.com/2005/01/08/national/08train.html.

Kaplan, D.E., Marshall, A., 1996. The Cult at the End of the World. Crown Publishers, Inc., New York, p. 85.

Kumar, S., 2004. Victims of gas leak in Bhopal seek redress on compensation. BMJ. 329, 366. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC509368/.

Landrigan, P.J., Carlson, J.E., Bearer, C.F., et al., 1998. Children's health and the environment: a new agenda for prevention research. Environ. Health Perspect. 106 (Suppl. 3), 787–794.

Morris, L., September 15, 2014. Islamic State Militants Allegedly Used Chlorine Gas against Iraqi Security Forces. Washington Post, online https://www.washingtonpost.com/world/middle_east/islamic-state-militants-allegedly-used-chlorine-gas-against-iraqi-security-forces/2014/10/23/c865c943-1c93-4ac0-a7ed-033218f15cbb_story.html.

National Fire Protection Association, 2007. NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response. http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=704&docnum=704&cookie_test=1.

National Institute for Occupational Safety and Health (NIOSH), 2002. Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks. CDC. www.cdc.gov/niosh/docs/2002-139/default.html.

National Oceanic and Atmospheric Administration (NOAA), 2015. Office of Response and Restoration Acute Exposure Guideline Levels (AEGLs). http://response.restoration.noaa.gov/oil-and-chemical-spills/chemical-spills/resources/acute-exposure-guideline-levels-aegls.html.

National Transportation Safety Board (NTSB), 1997. Aircraft Accident Report: In-flight Fire and Impact with Terrain, Valujet-Airlines Flight 592, DC-9-32, N904VJ. Everglades, near Miami, FL. NTSB/AAR-97/06 http://www.ntsb.gov/investigations/AccidentReports/Reports/AAR9706.pdf.

National Transportation and Safety Board (NTSB), 2005. Collision of Norfolk Southern Freight Train 192 with Standing Norfolk Southern Local Train P22 with Subsequent Hazardous Materials Release at Graniteville, SC. Railroad accident report NTSB/RAR-05/04 (PB2005–916304). Available at: http://www.ntsb.gov/news/events/Pages/Collision_of_Norfolk_Southern_Freight_Train_192_with_Standing_Norfolk_Southern_Local_Train_P22_at_Graniteville_South_Carol.aspx.

Olson, K.B., 1999. Aum Shinrikyo: once and future threat? Emerg. Infect. Dis. 5 (4), 513–516.

Occupational Safety & Health Administration (OSHA), 2015. Occupational Safety and Health Standards, Toxic and Hazardous Substances, Appendix A to §1910.1200—Health Hazard Criteria. Available at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=%2010100.

Organisation for the Prohibition of Chemical Weapons (OPCW), 2008. Nerve Agents: Lethal Organo-Phosphorous Compounds Inhibiting Cholinesterase (a FAO Briefing Book on Chemical Weapons). Available at: www.opcw.org/index.html.

Organisation for the Prohibition of Chemical Weapons (OPCW), 2015. Brief Description of Chemical Weapons. Available at: http://www.opcw.org/about-chemical-weapons/what-is-a-chemical-weapon/.

Pipeline and Hazardous Materials Safety Administration (PHMSA), 2008. Ten Year Hazardous Materials Incident Data. U.S. Department of Transportation. http://hazmat.dot.gov/pubs/inc/data/tenyr.pdf.

Shrivastava, P., 1987. Bhopal: Anatomy of a Crisis. Ballinger Publishing, Cambridge, MA.

Slater, M.S., Trunkey, D.D., 1997. Terrorism in America: an evolving threat. Arch. Surg. 132, 1059–1066.

Tucker, J.B., 1997. National health and medical services response to incidents of chemical and biological -terrorism. JAMA 278, 362–368.

Underwriters Laboratories (UL), 2008. Product Safety Tips: CO Alarms. www.ul.com/consumers/co.html.

United Nations (UN), 2007. Globally Harmonized System of Classification and Labeling of Chemicals (GHS), second revised ed. UNECE, United Nations. www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html.

United States Army Medical Research Institute of Chemical Defense (USAMRICD), 2000. Medical Management of Chemical Casualties Handbook, third ed. United States Army Medical Research Institute of Chemical Defense (USAMRICD), Chemical Casualty Care Division, Aberdeen Proving Grounds, MD. http://www.operationalmedicine.org/TextbookFiles/mmccthirdeditionjul2000.pdf.

United States Environmental Protection Agency, 2001. Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-to-know Act (EPCRA) and Section 112(r) of the Clean Air Act. EPA. http://www2.epa.gov/epcra/consolidated-list-lists.

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), 2003. Basic Questions Regarding Acute Exposure Guideline Levels (AEGLs) in Emergency Planning and Response. https://www.osha.gov/SLTC/emergencypreparedness/chemical/pdf/tier_2-aegls_basic_usachppm1_03.pdf.

U.S. Census Bureau (USCB), 2012. Nearly 1 in 5 People Have a Disability in the U.S., Census Bureau Reports: Report Released to Coincide with 22nd Anniversary of the ADA. Available at: https://www.census.gov/newsroom/releases/archives/miscellaneous/cb12-134.html.

9

Earthquakes

OBJECTIVES

- List the contributing factors to earthquake morbidity and mortality.
- Recognize the scales used to measure the intensity and magnitude of earthquakes.
- Describe the unique challenges associated with recognizing crush injuries.
- Explain the difference between crush syndrome and compartment syndrome.
- Provide examples of hazards to look for when assessing a home for earthquake risks.
- List the steps individuals can take to maximize their safety during an earthquake.
- Explain what an earthquake feels like and the initial actions that should be taken.
- Describe what the greatest opportunities are to reduce earthquake-related morbidity and mortality.
- Recognize the populations at greatest risk during a seismic event.
- List the key partners necessary for carrying out a public awareness campaign for earthquake preparedness.

Introduction: 1906 San Francisco Earthquake

Lloyd was a young boy living in San Francisco with his parents and baby sister. It was just after 5 am, and he was sleeping soundly on that early Wednesday morning when the shaking woke him. So frightened he could not scream, he buried his face under his pillow and held tightly to keep from being shaken out of bed. As he peeked out across his room from under his pillow, the knickknacks on his bureau danced vigorously and he could hear dishes and other loose items in the house rattling loudly. As soon as the shaking slowed, he bolted to his parents' room. His baby sister sat up quietly in her crib as his parents sat in stunned silence. As soon as the shaking subsided, the family moved quickly to the backyard. When an extended moment of calm arrived, they ventured back into the house to see the damage. As they swept up the broken dishes, vases, and other breakables, they looked out the front window to see their shocked neighbors lining the sidewalks in bewilderment.

As the day progressed, the family ran back and forth, leaving the house every time the shaking resumed until they finally decided to build a makeshift campsite in the backyard. As they began cooking over an open fire, the ash from the fires raging in San Francisco began to fall (Fig. 9-1). Lloyd's family stayed in its improvised tents for several days as those who were fleeing from the raging fires evacuated past their home to camps with clever names like Camp Grateful and Camp Thankful (Head, 1906; Watkins, 1981).

This family was among the lucky ones. Hundreds died from collapsing structures across San Francisco that day, and tens of thousands became homeless (Fig. 9-2). The final casualty numbers became a source of controversy. Although an initial Army report estimated about 500 deaths in San Francisco, just over 100 in San Jose, and 64 in Santa Rosa, more

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FIGURE 9-1 San Francisco, California earthquake, April 18, 1906. Downtown San Francisco—residents watching fires burn after the 1906 earthquake. *Photo by Ralph O. Hotz. Photo courtesy of the US Geological Survey.*

FIGURE 9-2 San Francisco, California earthquake, April 18, 1906. A ruined house on Shotwell Street. *Photo courtesy of US Geological Survey.*

recent estimates place the actual number beyond 3000 (Greely, 1906; Hansen and Condon, 1989). The recovery efforts following the earthquake were impressive. Military units began immediate response with no formal activation or call-up. In spite of the massive damage, civil order was quickly restored. A quarter of a million homeless residents were provided shelter through enormous tent cities and small modular housing, the forerunner

of today's FEMA trailers. A safe food and water supply was quickly established, and toilet facilities and other key sanitation necessities were set up. Aid poured in from around the nation and rebuilding efforts began almost immediately.

The public health impact of this disaster was felt for over a year. In addition to the injuries and fatalities resulting from collapsed structures and fires, an associated outbreak ignited nearly a year later. Although local public health authorities worked with public works, the military, and volunteers to reinstate healthy living conditions, there was one threat that was not fully addressed. At the beginning of the 20th century, bubonic plague had been brought into San Francisco by ships arriving in port that were carrying infected rats. Local officials initially ignored the 1900 plague outbreak among poor citizens living in Chinatown. In spite of a racially motivated and feeble public health response, the outbreak was brought under control. After the massive 1906 earthquake, the conditions were ripe for the reemergence of plague. The organism that causes the disease, *Yersinia pestis*, is carried by rats and transmitted to humans through the bites of fleas that have fed on infected rats. One year after the earthquake, a large plague outbreak spread across San Francisco. Between May and September 1907, there were 160 cases with 77 fatalities (Todd, 1909). These cases occurred predominantly among affluent white citizens.

There were several important differences in the public health response to the 1907 San Francisco, postearthquake plague outbreak compared with the Chinatown outbreak of 1900. More was understood 7 years later about the causes of plague and effective control measures. In addition, the city had just been through such a calamity that those rebuilding worked together with a greater sense of purpose than ever before. A massive effort was undertaken to clean up the city to exterminate rats and reduce their available food sources (see Fig. 9-3). Businesses, schools, and households were provided with detailed instructions on simple measures to reduce the rat problems across the city (see Fig. 9-4).

FIGURE 9-3 Eight public health service workers holding buckets filled with rat bait working to bring the 1907 San Francisco, California plague outbreak under control. *Photo courtesy of the National Library of Medicine.*

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CITIZENS HEALTH COMMITTEE

OF SAN FRANCISCO

HEADQUARTERS - 1233 MERCHANTS EXCHANGE BUILDING
TELEPHONE KEARNY 2183

EXECUTIVE COMMITTEE

CHAS. C. MOORE, CHAIRMAN
GUSTAVE BRENNER
WALTER MACARTHUR
GEO. H. EVANS, M. D.
FRANK J. SYMMES

SAN FRANCISCO, CAL.,

Important To Our Customers

Preservation of your business and the health of every person in San Francisco demand your instant and continued assistance in *exterminating RATS* and cleaning up the entire city.

The undersigned Associations are fully advised that a *quarantine* will be placed on the city *unless sanitary conditions* are made satisfactory to the federal government. Hence you are urged to give your personal attention to this matter.

Your business future depends upon the work you do to help the doctors.

San Francisco must be rid of rats within sixty days.

RATS SPREAD BUBONIC PLAGUE.

Fleas leave sick or dead rats and carry the plague to human beings.

Rats in San Francisco are infected with bubonic plague. There is no question about it, and every man, woman and child in the city must help the federal and city officials clean up.

Every line of trade must assist.

The Citizens Health Committee, advised by Dr. Rupert Blue of the United States Public Health and Marine Hospital Service, is directing the work.

GET BUSY and see that no open garbage cans are in your own or your neighbor's home or place of business. Don't leave food where rats can get it.

If quarantine is ordered you go out of business.

Enclosed are instructions prepared by the Health Committee and government inspectors.

Work, not complaints, is demanded. Notify Dr. Blue, 401 Fillmore Street; L. M. King, Secretary Citizens Health Committee, 1233 Merchants Exchange, or L. R. Levy, Secretary of the Beer Bottlers' Association, 524 Gough Street, of any insanitary condition in your neighborhood.

GET BUSY with rat traps and poison.

Make your scavenger do his work cleanly and often.

(Signed) BREWERS' PROTECTIVE ASSOCIATION.
S. F. BEER BOTTLERS' BOARD OF TRADE.
S. F. SODA WATER MANUFACTURERS' ASSOCIATION.
BOTTLERS' PROTECTIVE ASSOCIATION.

TEN THOUSAND OF THESE CIRCULARS WERE DISTRIBUTED TO THE SALOONS AND OTHERS OF THEIR TRADE BY THE ORGANIZATIONS SIGNING.

FIGURE 9-4 A 1907 flyer distributed to saloons and other alcohol serving establishments in the San Francisco area asking for assistance in bringing the postearthquake 1907 plague outbreak under control. *Image Courtesy of San Francisco Department of Public Health.*

This effort is considered to be one of the most effective public health responses to an outbreak in American history (Risse, 1992).

Earthquake-Related Definitions

Aftershock An earthquake of similar or lesser intensity following the main earthquake. Aftershocks are usually smaller than the initial shock and may occur days, weeks, months, or even years later. Larger earthquakes are usually followed by larger aftershocks over a longer period of time.

Crush injury An injury occurring when a body part experiences a high degree of pressure, usually under the weight of a heavy object. The resulting injuries include fractures, bruising, bleeding, lacerations, and compartment and crush syndromes.

Earthquake Ground shaking caused by an abrupt slipping or movement of a portion of the earth's crust, accompanied, and followed by a series of vibrations.

Epicenter The place on the earth's surface directly above the point of a fault line where an earthquake begins. Once fault slippage begins, it expands along the fault during the earthquake and can extend the impact hundreds of miles before stopping.

Fault The fracture across which displacement has occurred during an earthquake. It may also push up, down, or sideways. The slippage can range from less than an inch in a minor earthquake to more than 10 yards (9 m) in a severe earthquake.

Intensity The measured effect of an earthquake on people, buildings, or land. The two scales used to measure intensity are the Richter scale and modified Mercalli scale.

Liquefaction The behavior of loose soil when it loses strength and stiffness by earthquake shaking or other rapid loading. Soil deposits near rivers and beaches are particularly susceptible. As the resistance of the soil is compromised by water and vibration, structures are more likely to shift or collapse as the ground loses strength and acts more like a liquid.

Magnitude The amount of energy released during an earthquake, which is computed from the amplitude of the seismic waves. A magnitude of 7.0 on the Richter scale indicates an extremely strong earthquake. Each whole number on the scale represents 10-fold increase in force and an increase of about 30 times more energy released than the previous whole number. For example, an earthquake measuring 6.0 has an 10-fold increase in force and releases about 30 times more energy that one measuring 5.0.

Modified Mercalli scale This is a scale modified for North American conditions using Roman numerals I through XII to describe the effects observed by an earthquake. The lower numbers describe how an event is felt by people in the area and the larger numbers describe the expected damage. This is an arbitrary qualitative ranking based on observations rather than a mathematically derived scale.

Richter scale A logarithmic measurement of earthquake magnitude. Each whole number on the scale represents 10-fold increase in force and an increase of about 30 times more energy released than the previous whole number. For example, an earthquake measuring 6.0 has an 10-fold increase in force and releases about 30 times more energy that one measuring 5.0.

Seismic hazard The damage potential from seismic events. Seismic hazard depends on a variety of geological factors such as magnitude of an earthquake, distance from the epicenter, and type of soil and ground materials in the affected area.

Seismic waves Vibrations traveling outward from the earthquake fault at speeds of several miles/kilometers per second. Although fault slippage directly under a structure can cause considerable damage, the vibrations of seismic waves cause most of the destruction during earthquakes.

Tsunami Waves created by earthquakes and landslides. An earthquake can cause a sudden rise and drop of the sea floor setting in motion massive amounts of ocean water in the form of devastating surface waves traveling hundreds of miles/kilometers per hour.

Earthquakes

One of the most powerful and potentially devastating forces of nature is the energy contained in the earth's surface. Enormous tectonic plates comprising the earth's crust constantly slide together. There are points where stress accumulates. The violent shaking of an earthquake results from the sudden release of this energy and can collapse buildings, fracture roadways, and create tsunamis. Fatalities can easily reach into the thousands from a single event with additional hundreds of thousands of lives impacted. The intensity of these earthquake events is measured in two ways. The Richter scale is a logarithmic measurement of earthquake intensity (Table 9-1). Each whole number increase on this scale represents a 10-fold increase in force. In other words, a 6.0 earthquake is actually 10 times greater in magnitude than a 5.0. While the Richter scale measures event intensity, it was not designed to estimate consequential damage from a seismic event. The modified Mercalli scale uses Roman numerals I through XII to describe the effects observed by an earthquake. The lower numbers describe how an event is felt by people in the area and the larger numbers describe the expected damage. Both scales are rough estimates because there have not been consistent methods used to gather the data on which they are based. Although there is not a

Table 9-1 Comparison of Scales Used to Measure Earthquake Intensity With Damage Levels and Frequency

Modified Mercalli Scale		Damage Levels	Richter Scale	Approximate Frequency
I	Slightly detectable	Seldom felt or noticed; instrumentation detects occurrences	1.0–2.9	Tens of thousands per day
II–III	Sensed by some	Felt by some people, especially on upper floors of structures. Negligible damage with small, unstable objects displaced; vibration similar to a passing truck	3.0–3.9	Thousands per day
IV–V	Felt by nearly everyone	Slight damage with windows, dishes, glassware broken; furniture moved or overturned	4.0–4.9	Thousands per year
VI–VII	Moderate damage	Slight to moderate damage in well-built structures; considerable in poorly built structures; furniture and weak chimneys broken; masonry damaged; loose bricks, tiles, plaster, and stones fall	5.0–5.9	Hundreds per year
VIII	Destructive	Considerable structural damage, particularly to poorly built structures; chimneys, monuments, towers, elevated tanks may fall; frame houses moved; trees damaged; cracks in wet ground and steep slopes	6.0–6.9	Dozens per year
X	Disastrous	Most masonry and frame structures/foundations destroyed; some well-built wooden structures and bridges destroyed; serious damage to dams, dikes, embankments; sand and mud shifting on beaches and flat land	7.0–7.4	15 per year
XI	Very disastrous	Few or no masonry structures remain standing; bridges destroyed; broad fissures in ground; underground pipelines completely out of service; rails bent; widespread landslides	7.5–8.0	5 per year
XII	Catastrophic	Damage nearly total; lines of sight and level distorted; objects thrown into the air; damage for hundreds of miles	>8.0	1 every 5–10 years

Adapted from US Geological Survey and Federal Emergency Management Agency sources.

concise correlation between the two measures, both the US Geological Survey and Federal Emergency Management Agency have approximated the relationship of the two scales.

There are an array of variables which influence the morbidity and mortality resulting from a seismic event. On Good Friday, March 27, 1964, the second most powerful earthquake ever recorded in history hit the Prince William Sound area of Alaska (Fig. 9-5). The earthquake had a moment magnitude of 9.2 on the Richter scale and lasted for nearly 4 minutes. It was followed by nine aftershocks greater than 6.0 on the same day and many more in the subsequent weeks and months. It caused landslides, a tsunami, and direct damage to buildings in many major Alaskan cities but the death toll was only 131, including 115 in Alaska and 16 along the coastlines of California and Oregon (AEC, 2002).

FIGURE 9-5 Alaska Earthquake, March 27, 1964. This highway embankment fissured and spread as a result of liquefaction. The road was built on thick deposits of alluvium and tidal estuary mud. *Image courtesy of US Geological Survey.*

The Alaskan earthquake is in stark contrast to the 1976 Tangshan, China earthquake which registered just over 7.5 on the Richter scale and killed about a quarter million people (Peek-Asa et al., 2003). The difference between the two disasters underscores the risk factors for increased morbidity and mortality. How can an earthquake nearly 20 times greater in magnitude and hundreds of times more powerful, generate less than 1% of the casualties? The difference is a product of variables including individual human characteristics and behaviors, population density, time of day, weather, structural standards, distance from the epicenter, and geology. These and other factors all work together in a complex, dynamic process which determines the resulting morbidity and mortality. For example, a sturdy structure may be sitting in an area prone to liquefaction and collapse or a vulnerable structure may be located on solid ground and remain standing. In both cases, the occupants may react in such a way that may increase or decrease the likelihood of injury. If an earthquake occurs at night, there are likely to be a smaller number of injuries in suburban and rural

areas since fewer people will be in multistory and other vulnerable structures. However, this could be reversed in older urban areas where a large number of unstable multistoried residences could prove to be more dangerous locations than some of the newer office buildings.

The dynamic nature of these variables makes it very difficult to predict outcomes for various sized earthquakes. Perhaps the best effort to date in constructing a useful modeling tool is the multi-hazard loss estimation methodology earthquake model used in the Hazus-MH Earthquake Model. This is a valuable planning, training, and exercise tool developed by FEMA for federal, state, and local governments (FEMA, 2015). Although it has many limitations, it can produce rough morbidity and mortality estimates that are extremely valuable in preparedness training and exercises.

For preparedness initiatives, the two most influential determinants of morbidity and mortality are the built environment and human behavioral response to seismic events. Although the geological factors, timing, weather, and other factors cannot be changed, the built environment and human behavioral responses can be strengthened through a variety of awareness programs and related efforts. Much can be done to mitigate the impact of an earthquake in the built environment before, during, and after a seismic event. If an individual is in a relatively stable building but makes poor decisions regarding immediate actions, the survivability of the structure may not be enough to prevent serious human injury. For example, if individuals do not take cover but choose to run from the building while the seismic vibrations continue, they are at greater risk of being struck by falling debris from the façade of the building than to be injured from a building collapse. If the building is not stable, individuals who take appropriate cover along an inside wall or under a sturdy piece of furniture are more likely to remain in a survivable void space and be rescued later from the collapsed structure. Poor infrastructure and preparedness measures can result in high morbidity and mortality. The top 10 most lethal earthquakes are shown in Table 9-2.

It is not enough to put building codes into place across regions with increased risk for earthquake activity. For example, a 1999 earthquake centered near Izmit caused the collapse of buildings across seven Turkish provinces spanning an area over 150 miles (240 km). The earthquake registered 7.4 on the Richter scale and was one of the most devastating

Table 9-2 Top 10 Most Lethal Earthquakes

Rank	Year	Location	Fatalities	Magnitude
1	1556	Shensi, China	830,000	~8
2	1976	Tangshan, China	Official estimate = 255,000 Could be as high as 655,000	7.5
3	1138	Aleppo, Syria	230,000	Unknown
4	2004	Sumatra, Indonesia	227,898	9.1
5	2010	Haiti	222,570	7.0
6	856	Damghan, Iran	200,000	Unknown
7	1920	Haiyuan, Ningxia, China	200,000	7.8
8	893	Ardabil, Iran	150,000	Unknown
9	1923	Kanto, Japan	142,800	7.9
10	1948	Ashgabat, Turkmenistan	110,000	7.3

FIGURE 9-6 August 17, 1999 Izmit (Kocaeli) Turkey earthquake. There were probably four or five buildings of five- or six-story height in this area of Yuzbasilar. Looking at the debris, the buildings seem to have been fully occupied at the time of the quake. Most deaths occurred in these situations. *Photo courtesy of the NOAA National Geophysical Data Center.*

earthquakes of the 20th century (see Fig. 9-6). It left about a half million people homeless, tens of thousands injured, and over 30,000 dead (Reilinger et al., 2000). Turkey has always been a region prone to destructive seismic activity. Its history includes two 1939 earthquakes that killed about 30,000 each and over a dozen 20th-century seismic events measuring 7.0 or greater (NCEI, 2015). As a result, building codes were developed and instituted in Turkey over the course of several decades to reduce the vulnerability of new structures and make older structures less susceptible to collapse during an earthquake. Unfortunately, it was observed by engineers responding from around the world to assist in the 1999 earthquake recovery efforts that building codes, though in place, were seldom followed. As a result, many died who otherwise might have survived. Building codes and other public safety requirements are useless without enforcement.

The weather is one uncontrollable but extremely influential earthquake morbidity and mortality variable. Although weather has no influence on what goes on deep below the earth's surface where earthquakes originate, it plays a major role in the outcomes of those who survive the initial destruction and in the success of earthquake response and recovery efforts. Weather is a variable often overlooked during the planning and exercise process. Most full-scale preparedness exercises are conducted in the spring and summer months. This seasonal exercising can result in an underestimation of the complications faced in the aftermath of an earthquake. The distribution of fault lines does not favor areas with mild weather, meaning there is an equal chance of an earthquake in desert, arctic, or tropical conditions. In earthquake response efforts, weather seriously influences outcomes by inflicting additional environmental burdens on survivors and delaying the arrival of rescue teams and relief supplies. Such was the case in the aftermath of several 2008 earthquakes in Pakistan.

A 6.4 magnitude earthquake in southwestern Pakistan occurred on October 29, 2008. It killed several 100 and left tens of thousands homeless. Many homes across the region were constructed of mud brick which quickly crumbled during the shaking. In the devastated hill town of Ziarat, the district's health officer, Ayub Kakar, described the terrible living conditions of the survivors to the international media. The most immediate need was for shelter. Displaced persons, including vulnerable small children and elderly, were sleeping on the streets in extremely cold temperatures. The shelter problems were compounded by the lack of safe water and food across the region. According to Kakar, "Due to the cold, hundreds of children are being treated for pneumonia, abdominal diseases, diarrhea, and chest problems …" (Mansoor, 2008). If the disaster had occurred several weeks later, in the middle of winter, it could have been far worse. These postearthquake shelter problems in Pakistan followed just 3 years after the massive Kashmir earthquake which registered at a 7.6 magnitude and killed over 70,000, injured tens of thousands, and destroyed millions of homes. In the aftermath of the Kashmir disaster, the Relief Commissioner, C.B. Vvas, told the media the nation's response efforts had failed (USA Today, 2005a). He said there was an immediate need for 23,000 tents but could only come up with about 4000. Several days later, Prime Minister Shaukat Aziz told reporters, "We need tents, tents, tents, and prefab housing …" (USA Today, 2005b). It is understandable the massive 2005 earthquake response would fall short on needed resources. It was the worst earthquake in the nation's history. However, it is difficult to understand how 3 years later, when similar issues arose with a much smaller earthquake, it took at least four days to get shelters in place. Lessons learned from each catastrophe must be incorporated into future response operations.

We learn geology the morning after the earthquake.

Ralph Waldo Emerson

Earthquake Morbidity and Mortality Variables

1. Geological factors: Earthquake magnitude, local geological composition, and aftershocks
2. Geographical factors: Distance from epicenter, secondary emergencies generated in the immediate area such as fires and hazardous materials releases
3. Timing: The time of day, day of the week, time of year
4. Weather: Extreme cold or heat, excessive rain, and wind
5. Individual characteristics: Demographics such as age, sex, physical, and mental limitations, and previous earthquake experiences and preparedness awareness and training
6. Individual behavior: The actions taken by those at risk prior to, during, and immediately after an earthquake
7. Built environment: Type of building materials, number of stories, age, and condition, mitigation history for building contents as well as structural retrofitting
8. Community variables: Previous awareness and preparedness activities, social networks, medical, and first responder surge capacity

Human Health Effects

Earthquakes seldom cause direct injuries. The injuries are caused by the ensuing falling debris, collapsing structures, fires, and other hazards set in motion by seismic activity. A variety of traumatic injuries can result from an earthquake, ranging from minor cuts and bruises to serious burns, fractures, and crush injuries. There are also pulmonary challenges including the possibility of airway obstruction or asphyxiation from the large quantities of dust and debris generated by collapsing structures.

The January 12, 2010 earthquake in Haiti was a 7.0 magnitude event resulting in over 222,000 deaths and 300,000 injuries (see Fig. 9-7). The University of Miami Global Institute/Project Medishare (UMGI/PM) established one of the first field hospitals in Port-au-Prince. A review of UMGI/PM medical records from January 13 to May 28, 2010 provides a good synopsis of the postearthquake injuries. One-third of the 817 diagnoses were earthquake-related and the other two-thirds were other injuries experienced during recovery. The three leading earthquake injuries included fractures and dislocations (54%), wound infections/abscesses (37%), and crush injuries (25%). Most of these earthquake injuries were treated in the first four weeks following the disaster. Postearthquake recovery activities included the same top two diagnoses: fractures and dislocations (33%) and wound infections/abscesses (26%). However the third leading diagnosis during recovery was head, face, and brain injury (21%). Crush injuries dropped from being one quarter of the diagnoses to about 2% (CDC, 2011).

FIGURE 9-7 Devastating structural damage inflicted upon the country of Haiti in the aftermath of the 2010 earthquake. *US Public Health Service photo by Lt. Cmdr. Gary Brunette.*

Though traumatic injuries and airway management are well understood and readily managed by trained emergency medicine professionals, the earthquake-related injuries that pose the most unique challenges to healthcare providers and emergency medical personnel are crush injuries. Crush injuries were first recognized in early-20th-century earthquakes but were not clearly described. Patient management guidelines were not established for these injuries until World War II (Better, 1997). Crush injuries with prolonged entrapment are the most commonly observed in earthquake responses and rarely observed any other time. The fact that these injury types are so infrequent in other circumstances poses a preparedness challenge for clinical providers and rescue workers. To reduce crush injury morbidity and mortality, extensive care may be needed at the rescue site. To effectively prevent renal and cardiac failure, treatment must be started before and continued during extrication of patients from collapsed structures (Ron et al., 1984). Crush injuries include two distinct syndromes, crush syndrome and compartment syndrome.

Crush syndrome is the systemic manifestations of crushed muscle tissue and associated cell death. When a person with a crush injury is quickly extracted without any supportive care prior to and during the extraction, rapid death can result. Releasing the pressure on a crushed victim causes reperfusion of the blood carrying a large "dose" of damaged cells and toxic by-products to vital organs. It is sometimes referred to as the "Grateful Dead syndrome." This is due to the often quick and unexpected death of victims who moments earlier were expressing gratefulness toward rescuers for finally being extracted from entrapment. The sustained crushing force provides some protection for the victim by keeping the toxic substances produced by the injury from being circulated throughout the body. As soon as the crush pressure is released, a rush of toxic substances enters the bloodstream.

The Greta Hanshin-Awaji earthquake hit Kobe, Japan, in 1995 killing thousands. A review of 372 patients admitted to local hospitals with crush injuries indicated 74% of the crush injuries involved the lower extremities, 10% in the upper extremities, and 9% involved the trunk. Fifty of those crush injury patients (13%) died within several days of the earthquake. The cause of death was hypovolemia (decreased blood volume) and hyperkalemia (elevated blood potassium) (Oda et al., 1997).

Compartment syndrome results from pressure in a confined space of the body. The fascia is a tough tissue covering muscle groups throughout the body. It does not easily expand. As a result, when a fascia encased area is affected by trauma such as burns, contusions, fractures, or other injuries resulting in swelling, it is tightly contained in the compartment by the fascia. As internal pressure builds from the swelling, muscle tissue, nerves, and blood vessels are compressed. This compression reduces oxygen flow to the tissue, causing muscle and nerve cell death. The most influential factor in patients with bad outcomes from a compartment syndrome injury is a delayed diagnosis (Matsen and Clawson,

1975; McQuillan and Nolan, 1968; Rorabeck, 1984). One easy way to remember the keys to proper diagnosis is to use the "five Ps" (Olson and Glasgow, 2005). These include:

- Pain: Most common sign
- Paresthesia: Loss of feeling below the injury
- Passive stretch: Severe pain when the affected muscle is stretched
- Pressure: Obvious tenseness in the affected area
- Pulselessness: Less reliable sign

When extricating a trapped patient, it is often difficult to ascertain the level of crush injury risk. The patient may show no signs at all until after being extracted from entrapment (Michaelson, 1992). Managing a patient trapped in rubble experiencing a crush injury runs contrary to the usual "scoop and run" approach that is so much a part of emergency medicine in many countries. Because of the risk of crush injury sequelae, it is critical emergency medical professionals working in areas known to have seismic risks receive periodic training in the proper management of crush injuries. If their response to these injuries is approached with the same protocols as noncrush injuries, it can increase morbidity and mortality.

Demographic information on those injured and killed by earthquake-related injuries indicates there are fundamental population characteristics which influence survival outcomes. The risk of earthquake death increases with age and with the presence of disabilities for both adult women and men (Tanida, 1996). The risk also increases as age decreases below age 16, especially in less developed nations. Those with lower socioeconomic status are at increased risk of death and data suggests if their dwelling collapses, they are less likely to survive. Those with mental or physical disabilities, as well as those with physical illnesses, are also less likely to survive a serious earthquake (Boyce, 2000; Morrow, 1999; Osaki and Minowa, 2001).

On January 17, 1995, a 6.9 magnitude earthquake struck Kobe, Japan. It is also known as the Great Hanshin Earthquake. The demographic trends which emerged were shocking. Over 6000 people lost their lives. More than 50% of the fatalities were older than age 60. Among the cohort of elderly fatalities, there were twice as many female than male casualties. The death rate of those beyond age 80 was more than six times higher than people under age 50 (Tanida, 1996). There is typically a priority given in response to elderly, children, and other vulnerable populations in Japan. However, this disaster was so large, those who normally look out for individuals within those groups were busy taking care of their own families and could not attend to the needs of the most vulnerable populations.

As with many disasters which impact essential infrastructure, earthquakes can directly and indirectly pose countless threats to human health. For those relying upon medical devices and procedures, the loss of power can literally cut off lifelines. Those in need of dialysis or other life sustaining procedures are at risk. Many other vulnerable populations are at increased risk simply through the loss of basic environmental controls such as heating in cold climates and air conditioning in hot climates. The loss of power can also compromise perishable food supplies and increase the likelihood of foodborne disease outbreaks. Damage to water and sewer lines can contribute to increased health risks from

poor sanitation. History has clearly shown many opportunistic infections and vectors pose a growing threat to public health in the weeks and months following a major earthquake.

In April 2008, a 5.2 magnitude earthquake hit West Salem, Illinois. Immediately following this seismic event, the supervisor of the University of Iowa Hygienic Lab sent a message to state public health authorities warning that water from private wells could have a color change to black or yellow for up to a week following the earthquake which occurred in their neighboring state. This warning was based on the 2002 observation of private wells in Northeastern Iowa and Northern Illinois experiencing "black water events" following a November 2002 earthquake in Alaska, over 2500 miles away. The same thing happened in Iowa after the 1964 Good Friday earthquake in Alaska (AP, 2002; UI, 2008). There is clearly a risk of private well contamination following seismic events and following any moderate seismic event, neighbors in the surrounding area of several 100 miles should be reminded to watch for problems with their private water supply. As the magnitude of the seismic event increases, the area included in such a warning should also be expanded. Public health and utilities officials should diligently monitor for signs of sediment being stirred and introduced into private and public wells by seismic activity.

Human health can be at risk following an earthquake due to utility interruptions which sometimes include cascading complications. A recent example is the March 11, 2011 earthquake in Japan which led to massive problems at the Fukushima Daiichi Nuclear Power Plant (see Fig. 9-8). A 14 m high tsunami resulting from the earthquake disabled power to the facility. The fuel tanks required

FIGURE 9-8 Los Alamos National Laboratory Muon Radiography team members stand in front of the damaged Fukushima Daiichi reactor complex during a visit to determine if their emerging technologies could be used to image the location of nuclear materials within the reactor buildings. *Image courtesy of the Los Alamos National Laboratory.*

to provide generator backup power were also carried away by the tsunami. The compromise of the cooling system resulted in hydrogen explosions (Anzai et al., 2012). The explosions damaged the facility and resulted in a large volume of radioactive contamination throughout the region.

Although outbreaks of infectious disease do not normally occur after earthquakes, it is a possibility that should not be dismissed. The plague outbreak following the 1906 San Francisco earthquake was described earlier in this chapter. More recently, a rotavirus gastroenteritis outbreak occurred in Pakistan following the 2005 Kashmir earthquake (Karmakar et al., 2008). The possibility of an infectious disease outbreak cannot be dismissed following any major disaster impacting essential infrastructure. Federal, state, and local public health officials should diligently watch for occurrences of opportunistic infectious disease outbreaks following an earthquake or any other disaster.

Prevention and Preparedness

The most critical actions an individual can take to reduce the risk of injury during a seismic event are carried out prior to the event. Some believe preparedness for such a catastrophic disaster is not possible. However, earthquake preparedness is not only possible but essential. At the community level, it takes a multiagency, multidisciplinary approach. Prevention of earthquake-associated morbidity and mortality starts with minimizing construction projects in areas known to have high risk of earthquake damage. These areas have been well delineated and characterized. New construction should not occur on known fault lines. Detailed information on these zones is available from local planning and emergency management officials. For necessary construction projects near fault lines, building codes and engineering solutions must be incorporated to reduce the risk of collapsing structures. When structures collapse, there are void spaces created where trapped individuals may survive for hours or days before rescue. These void spaces can be maximized during the design process. In addition, the risk of suffocation from dust inhalation can be minimized by using materials that produce less dust during a collapse. If a structure cannot be hardened to prevent collapse during a seismic event, measures should be instituted making collapsing structures as survivable as possible for those who may be inside.

Enhancing individual and home preparedness requires an effective public education initiative. Much of this activity can be facilitated through working closely with the local media. Both print and broadcast media can raise awareness across a community concerning earthquake risks and mitigation measures. Engaging the media can be extremely beneficial by promoting preparedness and response stories on locating hazards and safe location within structures, shutting off utilities in the aftermath of an event, assisting vulnerable neighbors and family members, and finding additional detailed preparedness information. This information includes general preparedness material available through the Red Cross and local, state, and federal emergency management organizations. Details on shutting off utilities may be obtained and promoted

through utility companies. A variety of public and private organizations, including businesses, public, and private schools, faith-based organizations, advocacy organizations for vulnerable populations, and other local organizations can be recruited to support the development and sharing of essential earthquake preparedness information in regions known to have potential seismic activity. However, there is a challenge as there is no single set of rules for the most appropriate actions to take during an earthquake. There are stories of individuals running out of a building during an earthquake and being killed by falling debris from the building's façade (see Fig. 9-9). There are also reports of those in similar situations who chose to stay inside and perished in a building collapse. Rather than training people to do something specific, training should focus on staying calm and thinking rationally during an earthquake. If those at risk are trained to look for certain types of hazards before and during a seismic event, the risk of injury or death can be greatly reduced.

FIGURE 9-9 Loma Prieta, California earthquake, October 17, 1989, San Francisco. Cars crushed by a collapsed brick facade near 5th and Townsend. Five people were killed at this location while leaving work. *Photo courtesy of the US Geological Survey.*

Hazard Hunts

The public should be instructed to minimizing earthquake injury risks in a home by searching for and securing any items that can fall or break, causing injuries. This includes heavy items that can fall and injure an occupant; hazardous materials that can be released from spilled containers or ruptured pipes; electrical hazards from broken or fallen wires; and fire risks from gas lines and appliances.

Structural hazard assessment begins with a room-by-room evaluation. Starting with the ceiling, anything suspended should be secured, including recessed light fixtures. If suspended items are not securely anchored, they could pose a hazard. Heavy items hanging on the walls must be anchored to prevent falling. This is especially true for items hanging near beds, couches, chairs, and anywhere else where people may lie or sit. Heavy items hanging over these areas must be moved or braced so they cannot fall or strike someone during an earthquake. Heavy items on shelves should be placed on lower shelves and tall furniture, such as shelving units, should be secured to wall studs. Breakable items should be placed in cabinets with strong latches. Any hazardous materials should be segregated by chemical compatibility and stowed inside latched cabinets. Water heaters should be strapped to wall

FIGURE 9-10 A water heater anchored to the walls and with a flexible gas line connection which can prevent a gas line break during a seismic event. *Photo courtesy of the California Department of General Services, Division of the State Architect.*

studs. A gas water heater poses particular risks during a disaster. If knocked over during an earthquake, a water heater not only can cause serious water damage; it also can cause a gas leak leading to an explosion and fire. The water heater should be located between 1 and 12 in. from a wall. Using flexible steel straps (plumber's tape), the water heater should be secured to wall studs on both sides of the water heater. At least two straps should be used. The top strap should be about 6 in. from the top of the water heater and the bottom strap should be about 6 in. from the bottom. In high-risk areas, this preventive measure may be doubled at the top and bottom with one strand of plumber's tape wrapped clockwise and the other counter clockwise at the top and the bottom sections of the water heater. The straps should be securely mounted to wall studs. The rigid gas connections on water heaters should be replaced with flexible connectors (see Fig. 9-10) to minimize the risk of a broken gas line.

Individual Preparedness Messages

Once a structure has been made as safe as possible, the individual actions to be taken during an earthquake must be determined and practiced in advance. A safe location should be selected in each room of a home, workplace or anywhere occupants spend a considerable amount of time. The safe location may be under a large piece of furniture or simply along an inside wall on which there are no heavy objects hanging. The key to finding the safest place in the room is to look above each potential spot to see what can fall and break. Anything heavy or containing glass should be avoided. If there is a sturdy piece of furniture that can be used as a shield, it should be used for cover. For example, the fallen light fixtures and partitions in Fig. 9-11 could cause serious injury to office workers if they have not

FIGURE 9-11 Failure of office partitions, ceilings, and light fixtures in the 1994 Northridge Earthquake. *Image courtesy of the Federal Emergency Management Agency.*

been taught in advance to take cover under their desks during an earthquake. A plan for immediate action should include practicing the "drop, cover, and hold on" procedure. A safe location should also be identified outside away from buildings, power lines, and other hazards. Individuals should be trained on basic first aid, the use of fire extinguishers, procedures for shutting off utilities, and communication planning using out of town contacts.

Immediate Actions

An earthquake initially presents in a variety of ways depending on the magnitude of the seismic activity, distance from the epicenter, and location of the individual (eg, inside, outside, in a car, etc.). Those near the epicenter of a large earthquake will feel an abrupt jolt. It may knock down those who are standing and even make it difficult to stay in bed if it occurs at night. The initial jolt can be followed by violent shaking lasting up to several minutes. The further away from the epicenter, the gentler the initial jolt. Those farther away from the epicenter may feel a gentle bump followed several seconds later by stronger shaking. If it is a small, nearby earthquake, it may feel like a smaller jolt followed by several stronger shakes which dissipate quickly (USGS, 2015). The most important immediate action for all affected is to stay calm.

A familiar phrase memorized by children on actions to take should their clothing catch fire is, "STOP, DROP, and ROLL." A similar phrase promoted by the Federal Emergency Management Agency should be as familiar for those living in earthquake prone regions: "DROP, COVER, and HOLD." Preparedness messages should include instructions to immediately drop to the floor, take cover under a sturdy table or other piece of furniture, and hold on as soon as an earthquake begins. If there is no sturdy piece of furniture to use for cover the individual should move to an inside wall. Historically, many partially collapsed structures lose external walls while the internal sections remain intact. Individuals should also stay away from tall, heavy furniture with the potential to fall and from heavy items hanging on walls that could fall and cause injuries; avoid windows, pictures, and mirrors; and stay inside until the shaking stops. Many injuries occur when those inside a building attempt to move around inside or attempt to exit. Those exiting a building should avoid using elevators and also be aware the electricity may go out or the fire alarms or sprinkler systems may activate.

Those who are outside should stay outside but quickly move away from overhead electrical lines and tall trees or buildings. Once the shaking stops they should stay away from buildings. Most injuries during earthquakes occur when people are running into, out of, or are simply near buildings that collapse or drop debris during or immediately after an earthquake (see Fig. 9-12). Those driving should stop on the side of the road as soon as it is safe to do so and stay in their vehicle until the shaking stops. They should not stop on or under bridges, near power lines, multistory buildings or large road signs. Once the shaking stops they should proceed slowly and avoid bridges or ramps which may have been damaged. This advice may have prevented some of the 33 fatalities that occurred during the 1994 Northridge earthquake in Los Angeles County. Of the 33 fatalities reported, 26 were injured indoors and six outdoors. Five of the six who died outdoors perished in car accidents, the sixth was electrocuted (Peek-Asa et al., 1998).

FIGURE 9-12 Mexico City Earthquake, September 19, 1985. The top floors of this eight-story building collapsed because of pounding against surrounding buildings. *Photo courtesy of the US Geological Survey.*

Response and Recovery

Once a seismic event is over, the immediate actions taken should be dictated by the surroundings. Those affected should ensure they are not injured and then take immediate action to remain safe and uninjured. Immediate actions may include shutting down utilities to avoid fire and electrocution risks. As soon as the area is made as safe as possible, attention should turn to vulnerable friends and neighbors. The vast majority of those rescued from collapsed structures are not rescued by professional first responders or urban search and rescue team members but rather by untrained individuals nearby who are uninjured and make the decision to assist others. Those engaged in an initial rescue effort should be aware of potential aftershocks as they turn off utilities to damaged structures or seek out injured individuals. The use of anything which could generate a spark or flame should be avoided and sturdy shoes should be worn by anyone participating in initial rescue and recovery activities. Particular attention should be paid to electrical hazards and hazardous materials that could have been spilled or released during the earthquake. Those who live near the coastline should also be aware of tsunami risks and avoid being near the beaches.

It is important to emphasize, "freelance" rescue workers should not be encouraged or condoned. In most major disasters, well-intentioned individuals without appropriate training or equipment, place themselves and others in danger by trying to carry out complex or technical rescues they are not capable of performing. Many who are trapped after an earthquake can only be safely rescued by professional first responders or search and rescue teams. Conversely, able-bodied survivors are the source for the

majority of initial rescues. In some situations, waiting for professionals to arrive will cost valuable time and could cost lives which otherwise might be saved. This underscores the need for community preparedness training for potential spontaneous volunteers in high-risk areas where technical rescues by professional teams may come a day or two later. Basic awareness of postearthquake hazards is essential for anyone living near an earthquake prone region in order to provide enough information to allow for safe, spontaneous rescue efforts while maintaining cognizance of situations requiring specialized rescue teams.

Following an earthquake, those providing medical care to the acutely injured should plan on 3–5 days of periodic patient surge. Those caring for the chronically ill should ensure they have taken measures to maintain continuity of care (Leor et al., 1996). This continuity of care includes ensuring an adequate supply of prescription medications, availability of dialysis or home care services, and other medical necessities. Public health authorities should step up surveillance activities, to include documenting acute injuries, including when, where, and how injuries occur, as well as communicable diseases emerging due to compromised infrastructure.

Media advisories are an integral part of the healthcare and public health response. Appropriate warnings for physical and environmental hazards should be shared and should also include advice for injury prevention. These messages should not be developed exclusively during the postdisaster phase. Prior to any major seismic event, public health and medical professionals should already have templates established to share essential postearthquake information. Although there are regional risk communication issues requiring content changes, the majority of the core public messaging needed will remain the same regardless of location.

The transition from rescue to recovery is one of the most difficult and controversial issues facing decision-makers when dealing with collapsed structures. An urban search and rescue operation is a dangerous and costly process. As long as there is a reasonable hope survivors may still exist, it is a moral imperative to do everything possible to carry out extractions. The key question is how long it is reasonable to assume the possibility of survivors when rescue workers are at risk and resources are needed for survivors. There is a time when a declaration must be made shifting the operation from rescue to recovery. In the aftermath of the September 11, 2001, terrorist attacks and collapse of the World Trade Center in New York City, Mayor Rudy Giuliani had to make the decision on when to issue death certificates for those not found and to transition Ground Zero rescue operations to recovery operations. The same challenge exists for any collapsed structure. The decision to move from rescue operations to recovery in the World Trade Center disaster was made 14 days after the building collapse (Cooper, 2001). Although it is rare, survivors have been found two weeks or more from the initial impact and immediate response. All morbidity and mortality variables must be considered when making this decision. Depending upon the conditions, the declaration of a transition from a response to a recovery operation may be sooner than 14 days but will rarely exceed that time.

Summary

Earthquakes are one of the most destructive and unpredictable forces of nature. Fortunately, there are a variety of opportunities to reduce associated morbidity and mortality. Although the day and time of earthquakes cannot be predicted, the majority of locations with the greatest potential for devastating seismic activity are well defined. Like many other catastrophic disasters, minimizing earthquake-associated injuries and fatalities requires a multidisciplinary and multiagency approach. It includes adequate and enforced building codes. Healthcare preparedness initiatives must include training on the coordination of mass care and management of crush injuries. Training and exercise scenarios should incorporate as many challenging variables as possible, such as poor weather and damaged transportation routes.

In all preparedness initiatives, a special focus must be placed on vulnerable populations. Family members and home healthcare providers should be engaged to offer preparedness guidance to vulnerable elderly, disabled or ill individuals residing in private homes. Initial actions and evacuation procedures should be discussed and practiced. Beds should be relocated to the safest area of the home away from windows and outer walls and without heavy objects or unanchored light fixtures over them. Large facilities such as hospitals and nursing homes should have comprehensive emergency plans going beyond fire evacuation or immediate sheltering for a tornado. Evacuation plans should be developed and coordinated with emergency management professionals in the community. Unfortunately, some plans appear good on paper but lack proper coordination. If preparedness planning is not coordinated with others in the community, operationalizing the plans during an emergency will fail. For example, if a long-term care facility plans on using a specific bus service for resident evacuation, they must ensure the bus service has an agreement in place with them, without a competing agreement with other facilities, which could delay or prevent their evacuation. Planning assumptions must be discussed and coordinated in advance. Otherwise, even the best plans can come unraveled due to unanticipated external weaknesses.

Community awareness and education initiatives offer the greatest opportunities to reduce earthquake-associated morbidity and mortality. Simple and inexpensive measures to reduce the risks of falling objects, broken glass, fire, and electrocution as well as individual self-protection measures during and immediately following an earthquake are all topics which should be regularly addressed with populations at risk. This can be done through working closely with schools, community, and advocacy organizations, and the local media.

Websites

American Red Cross, Earthquake Preparedness. http://www.redcross.org/prepare/disaster/earthquake.

California Department of Public Health, Earthquakes. http://www.bepreparedcalifornia.ca.gov/beinformed/naturaldisasters/earthquakes/Pages/Earthquakes.aspx.

Centers for Disease Control and Prevention, Emergency Preparedness and Response, Earthquakes. http://emergency.cdc.gov/disasters/earthquakes/.

City of Berkeley, CA, Homeowner Guide to Earthquake Safety, Earthquake Hazard Hunt. http://www.ci.berkeley.ca.us/uploadedFiles/Fire/Hazard%20Hunt-5.pdf.

City of Los Angeles, CA, Department of Building Safety, How You Can Strengthen Your Home for the Next Big Earthquake in the Los Angeles Area. www.cert-la.com/BAS-How-You-Can-Strengthen-Your-Home.pdf.

City of Los Angeles, CA, Fire Department, Earthquake Preparedness Handbook. http://www.cert-la.com/EmergPrepBooklet.pdf.

Earthquake Country Alliance, Southern California Earthquake Center at USC. http://www.earthquakecountry.org/.

Federal Emergency Management Agency (FEMA), Earthquakes. http://www.fema.gov/earthquake.

Federal Emergency Management Agency (FEMA), Earthquake Publications. http://www.fema.gov/earthquake-publications.

Federal Emergency Management Agency (FEMA), Ready.gov, Earthquakes. http://www.ready.gov/earthquakes.

Insurance Institute for Business and Home Safety (IBHS), Earthquakes. https://www.disastersafety.org/earthquake/.

National Child Traumatic Stress Network (NCTSN), What You Should Know about Earthquakes. http://www.nctsn.org/trauma-types/natural-disasters/earthquakes.

National Earthquake Hazards Reduction Program. www.nehrp.gov/.

National Geophysical Data Center (NGDC), Earthquake Intensity Database. www.ngdc.noaa.gov/hazard/earthqk.shtml.

Occupational Safety & Health Administration, Earthquakes Guide. https://www.osha.gov/SLTC/emergencypreparedness/guides/earthquakes.html.

Pacific Earthquake Engineering Research Center. http://peer.berkeley.edu/.

U.S. Geological Survey, American Red Cross, Asian Pacific Fund, California Earthquake Authority, Governor's Office of Emergency Services, New America Media, U.S. Department of Homeland Security, and the Federal Emergency Management Agency, Protecting Your Family from Earthquakes-the Seven Steps to Earthquake Safety (In English, Chinese, Vietnamese, and Korean). http://pubs.usgs.gov/gip/2007/42/.

U.S. Geological Survey, Earthquake Hazards Program. www.earthquake.usgs.gov/.

Washington State Department of Health, Earthquakes. http://www.doh.wa.gov/Emergencies/EmergencyPreparednessandResponse/Factsheets/Earthquakes.

World Health Organization (WHO) Earthquakes – Technical Hazard Sheet – Natural Disaster Profile. http://www.who.int/hac/techguidance/ems/earthquakes/en/.

References

Alaska Earthquake Center (AEC), 2002. The Great Alaska Earthquake of 1964. Available at: http://www.aeic.alaska.edu/quakes/Alaska_1964_earthquake.html.

Anzai, K., Ban, N., Ozawa, T., Tokonami, S., January 2012. Fukushima Daiichi nuclear power plant accident: facts, environmental contamination, possible biological effects, and countermeasures. J. Clin. Biochem. Nutr. 50 (1), 2–8.

Associated Press (AP), November 08, 2002. Earthquake in Alaska Disrupted Drinking Wells. NWI.com. Available at: http://www.nwitimes.com/news/local/earthquake-in-alaska-disrupted-drinking-wells/article_c9e6685a-6b1a-5fe8-ad0c-767dff4ca961.html.

Better, O.S., 1997. History of the crush syndrome: from the earthquakes of Messina, Sicily 1909 to Spitak, Armenia 1988. Am. J. Nephrol. 17 (3–4), 392–394.

Boyce, J.K., 2000. Let them eat risk? Wealth, rights and disaster vulnerability. Disasters 24, 254–261.

Centers for Disease Control and Prevention (CDC), 2011. Post-earthquake injuries treated at a field hospital—Haiti, 2010. MMWR 59, 1673–1677. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5951a1.htm.

Cooper, M., 2001. A Nation Challenged, the Trade Center: Guiliani Declares that Finding Anyone Still Alive in the Rubble Would Be "A Miracle." The New York Times. September 25, 2001:B9.

Greely, A.W., 1906. Relief Operations Conducted by the Military Authorities of the United States at San Francisco and Other Points, Special Report. U.S. Government Printing Office, Washington, DC.

Federal Emergency Management Agency (FEMA), 2015. Hazus-MH Earthquake Model. Available at: https://www.fema.gov/hazus-mh-earthquake-model.

Hansen, G., Condon, E., 1989. Denial of Disaster: The Untold Story and Photographs of the San Francisco Earthquake of 1906. Cameron and Co., San Francisco, CA, p. 160.

Head, L., July 28, 1906. One boy's experience: a member of the Roosevelt Boys' Club writes of his experience during and after the Great Earthquake. Roosevelt Boys' Club's Newsl. www.sfmuseum.net/1906/ew7.html.

Karmakar, S., Rathore, A.S., Kadri, S.M., et al., 2008. Post-earthquake outbreak of rotavirus gastroenteritis in Kashmir (India): an epidemiological analysis. Public Health 122 (10), 981–989.

Leor, J., Poole, W.K., Kloner, R.A., 1996. Sudden cardiac death triggered by an earthquake. N. Engl. J. Med. 334 (7), 413–419.

Mansoor, H., November 1, 2008. Disease Hits Freezing Quake Zone. Agence France-Presse.

Matsen, F.A., Clawson, D.K., 1975. The deep posterior compartmental syndrome of the leg. J. Bone Jt. Surg. Am. 57, 34–39.

McQuillan, W.M., Nolan, B., 1968. Ischaemia complicating injury: a report of thirty-seven cases. J. Bone Jt. Surg. Br. 50, 482–492.

Michaelson, M., 1992. Crush injury and crush syndrome. World J. Surg. 16 (5), 899–903.

Morrow, B.H., 1999. Identifying and mapping community vulnerability. Disasters 23, 1–18.

National Centers for Environmental Information (NCEI), 2015. National Oceanic and Atmospheric Administration (NOAA). Significant Earthquake Database. Available at: http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=1&d=1.

Oda, J., Tanaka, H., Yoshioka, T., et al., 1997. Analysis of 372 patients with crush syndrome caused by the Hanshin-Awaji earthquake. J. Trauma 42 (3), 470–476.

Olson, S.A., Glasgow, R.R., 2005. Acute compartment syndrome in lower extremity musculoskeletal trauma. J. Am. Acad. Orthop. Surg. 13 (7), 436–444.

Osaki, Y., Minowa, M., 2001. Factors associated with earthquake deaths in the great Hanshin-Awaji earthquake, 1995. Am. J. Epidemiol. 153, 153–156. http://aje.oxfordjournals.org/content/153/2/153.full.

Peek-Asa, C., Kraus, J.F., Bourque, L.B., et al., 1998. Fatal and hospitalized injuries resulting from the 1994 Northridge earthquake. Int. J. Epidemiol. 27 (3), 459–465. http://ije.oxfordjournals.org/cgi/reprint/27/3/459.pdf.

Peek-Asa, C., Ramirez, M., Seligson, H., et al., 2003. Seismic, structural, and individual factors associated with earthquake related injury. Inj. Prev. 9, 62–66.

Reilinger, R., Toksoz, N., McClusky, S., Barka, A., January 2000. 1999 Izmit, Turkey earthquake was no surprise. GSA Today 10 (1). Available at: http://www.geosociety.org/gsatoday/archive/10/1/article/i1052-5173-10-1-1.htm.

Risse, G.B., 1992. A long pull, a strong pull, and all together: San Francisco and bubonic plague, 1907–1908. Bull. Hist. Med. 66, 260–289.

Ron, D., Taitelman, U., Michaelson, M., et al., 1984. Prevention of acute renal failure in traumatic rhabdomyolysis. Arch. Intern. Med. 144, 277–280.

Rorabeck, C.H., 1984. The treatment of compartment syndromes of the leg. J. Bone Jt. Surg. Br. 66, 93–97.

Tanida, N., 1996. What happened to elderly people in the great Hanshin earthquake. BMJ. 313 (7065), 1133. www.bmj.com/cgi/content/full/313/7065/1133.

Todd, F.M. (Ed.), 1909. Eradicating Plague from San Francisco: Report of the Citizens' Health Committee and an Account of Its Work. Murdock & Co., San Francisco, CA.

University of Iowa (UI), April 21, 2008. University Hygienic Laboratory Newsletter. (2008). Earthquake Causes Ripple Effect at UHL. www.uhl.uiowa.edu/publications/tw@uhl/2008/04-21-08/04-21-08.pdf.

USA Today, October 11, 2005a. Many Villages in Kashmir Still Seeking Assistance. www.usatoday.com/news/world/2005-10-11-india-seeking-aid_x.htm.

USA Today, October 16, 2005b. Weather Hampers Pakistani Earthquake Rescue and Relief. www.usatoday.com/news/world/2005-10-16-earthquake-asia_x.htm.

U.S. Geological Survey (USGS), 2015. Earthquake Effects & Experiences FAQs. Available at: http://www.usgs.gov/faq/categories/9829/3365%20.

Watkins, E., 1981. The 1906 San Francisco earthquake: a personal account. Calif. Geol. 34, 12. http://www.johnmartin.com/earthquakes/eqpapers/00000047.htm.

10

Emerging and Reemerging Infectious Disease Threats

OBJECTIVES

- Describe why diseases "emerge" or "reemerge."
- Discuss the impact of emerging infectious diseases on public health preparedness.
- List the likely sources of emerging infectious diseases in the future.
- Describe how international travel and commerce contribute to emerging infectious disease threats.
- Discuss how microbial adaptation contributes to emerging infectious disease threats.
- List human demographic factors and behaviors contributing to emerging infectious disease threats.
- Identify the epidemiological clues indicating a possible emerging disease.
- Describe various types of surveillance approaches.
- Discuss the breakdown of public health measures and systems.
- Recognize the actions needed for responding to an emerging disease.

Introduction: A Tale of Three Diseases

West Nile Virus

On a Friday afternoon before the Labor Day holiday weekend in 1999, the phone at the New York City Department of Health was answered by the on-call epidemiologist. An infectious disease specialist was calling to report an unusually large number of encephalitis or meningitis cases (inflammation of the brain or covering of the brain and spinal cord) at several hospitals in the borough of Queens. Blood and spinal fluid were tested at the New York State and CDC laboratories and reported positive for Saint Louis encephalitis virus (SLEV), a virus known to occur in the United States but never in New York City. New York City officials immediately began mosquito control programs in an attempt to stop transmission from mosquitoes, the vector for SLEV. Over the next week, test results appeared to be conflicting. Unknown to many of the investigators of the human outbreak, a veterinarian at the Bronx Zoo was investigating an outbreak of central nervous system disease in birds. Wildlife veterinarians were also observing large bird die-offs but could not find a clear cause. By mid-September, both sets of investigators believed the causative agent was not SLEV. By September 27, after expanding testing services to several federal and academic laboratories as well as to the wider family of *Flaviviridae*, it was confirmed that the causative agent for the human outbreak, the avian outbreak, and sentinel mosquito sampling was West Nile virus (see Fig. 10-1). By 2000, the New York City outbreak

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FIGURE 10-1 A Culex quinquefasciatus mosquito is known as one of the many arthropodal vectors responsible for spreading arboviral encephalitis or West Nile virus to human beings through their bite. *Photo by James Gathany courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

included 62 confirmed cases and 7 deaths (Johnston and Conly, 2000). By that time, the West Nile virus was documented as having spread halfway across the United States to the Rocky Mountains (Roehrig, 2013).

Influenza A H1N1v

On April 15, 2009, a sample was routinely tested from a young girl with influenza-like illness as part of the US sentinel influenza network. The results indicated this was a uniquely novel strain of influenza A (see Fig. 10-2). On April 17, 2009, a similar result was confirmed 130 miles from the originally identified case. Testing also confirmed that this virus was resistant to both amantadine and rimantadine but sensitive to both oseltamivir and zanamivir, two readily available antiviral medications. There had been sporadic cases of influenza with infection of viruses in the swine lineage, and it was suspected and later confirmed that this novel influenza A, H1N1, was a unique combination of genes most closely related to North American swine-lineage H1N1 and Eurasian swine-lineage H1N1. In the two initial cases, no contact with pigs was discovered through extensive investigation, and it was determined that this novel virus had been spread to these cases by human-to-human transmission, a new behavior for H1N1. By April 23, additional cases were identified in Texas, and samples collected from an outbreak in Mexico were also positive for this new strain. By April 26, a public health emergency, the first in the history of the United States, was declared to allow for the rapid development of a vaccine, mobilization of antiviral medications through the federally resourced Strategic National Stockpile, and enhanced surveillance through reporting and testing. Travel advisories were put into place, and upon discovery of additional cases internationally, the World Health Organization (WHO) raised the pandemic level from phase 4 to the pandemic level phase 5. The largest number of cases occurred in people between the ages of 5 and 24 years old. Major

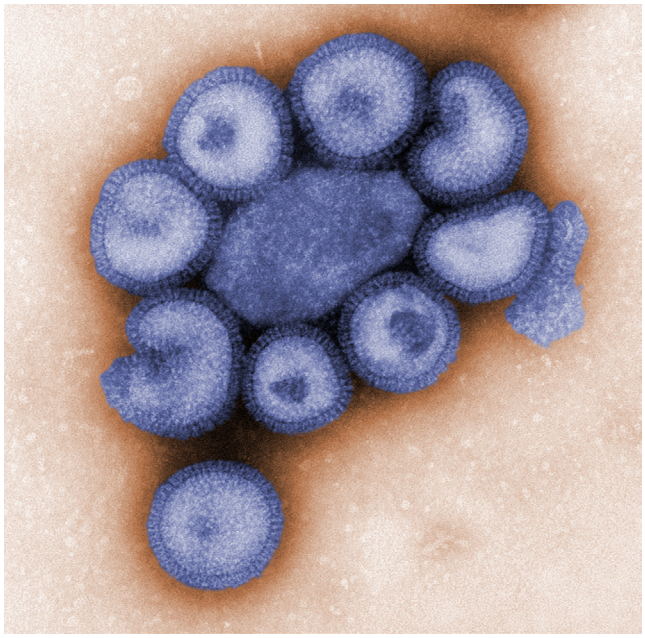

FIGURE 10-2 This negative-stained transmission electron micrograph depicts the ultrastructural details of a number of influenza virus particles or "virions." *Photo by Dr. F.A. Murphy courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

morbidity (illness) and mortality (death) occurred in pregnant women, and middle-aged people with chronic diseases and obesity, but overall the fatality rate was low. Few cases were reported in people over the age of 65, indicating that this group may have had immunity. Levels of influenza illness remained high in the summer of 2009, unusual for the North American continent. Rapid molecular analysis of the viral genome led to rapid production of a vaccine. In the late summer, the Food and Drug Administration announced the monovalent vaccine would be licensed via a "strain change" pathway, which is similar to how seasonal influenza vaccines are licensed. This meant production would be expedited, since the same methods would be used as those used to produce seasonal flu vaccine and additional safety and validation studies would not need to be completed. By September, 2009, 5 months after the first case was identified, prototype vaccine was delivered to US states for use. H1N1 is now included in seasonal vaccines (Gatherer, 2009).

Ebola Virus Disease

Ebola virus disease (EVD) was first described in 1976 in two simultaneous outbreaks in sub-Saharan Africa. In December 2013, a small outbreak of EVD was reported in a forested area in southeastern Guinea (see Fig. 10-3). It has been postulated that the index case, a boy, was in direct contact with bats. This was the 26th reported Ebola outbreak in history but the first to be reported in West Africa. EVD then spread to Liberia and Sierra Leone, all

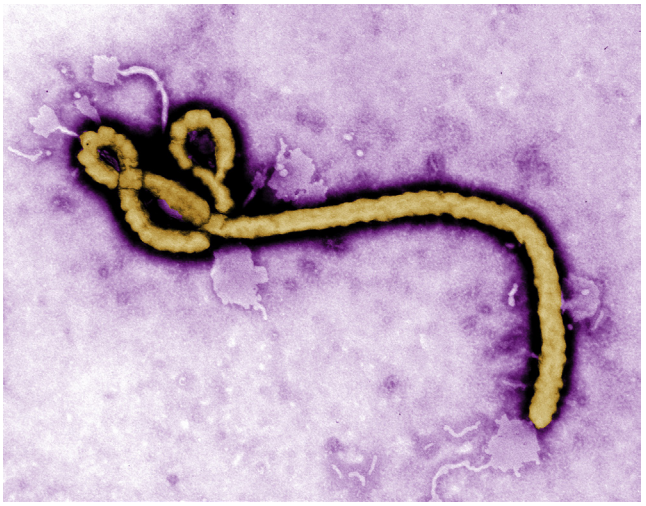

FIGURE 10-3 Transmission electron micrograph revealed some of the ultrastructural morphology displayed by an Ebola virion. *Photo by Dr. F.A. Murphy courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

through direct contact with the outbreak in Guinea (WHO, 2014). In Guinea, Liberia, and Sierra Leone as of August 13, 2015, there have been over 28,000 cases and 11,000 deaths. A small outbreak of 20 cases occurred in Nigeria, and one case occurred in Senegal. Several cases were reported outside of the area, mostly in healthcare or humanitarian workers returning to their home countries. There were also imported cases in the United States and Spain which led to secondary infections of medical workers but did not spread further. In both countries, the management of companion animals and environmental cleanup were challenging issues. Several factors contributed to the devastation of this epidemic: poverty, population density, infrastructure decline after years of armed conflict, serious gaps in health and medical infrastructure with little to no surge capacity, and a delay in coordinated response. In spite of the significant risk to underresourced healthcare workers (comprising 10% of the dead), a major humanitarian medical response was launched internationally. In October 2014, controls on people traveling out of the area went into effect with exit screening for symptoms, entry screening in most countries, and active monitoring of travelers in some countries after arrival. This screening program controlled movement and by actively monitoring attempts to identify people who may become ill early in the course of the disease, getting them to healthcare in a controlled manner and with appropriate infection control practices in place. Healthcare facilities and providers in many countries stockpiled personal protective equipment, implemented infection control training, and implemented screening processes in order to be prepared. On January 28, 2015, the WHO reported for the first time since the week ending June 29, 2014, that there had been fewer than 100 new confirmed cases reported. The focus of the response shifted from slowing transmission to ending the epidemic. In July 2015, results of early testing of a vaccine appeared very promising. By the end of 2015, the Ebola Outbreak in West Africa reached over 28,000 cases and 11,000 deaths making it the largest Ebola outbreak in

history (CDC, 2015). Prior to this, the largest was a 2000–2001 Uganda outbreak with 425 cases and 224 deaths (CDC, 2001). At the time this chapter was written, public health professionals around the world continued to watch closely the progression toward stopping, and continued success in recovering from, this devastating Ebola epidemic.

Emerging Infectious Disease Definitions

Bacteria Plural of bacterium. A single-celled microorganism that can exist independently as a free-living organism or as parasite dependent upon a host organism.

Emerging Infectious Diseases Illnesses caused by pathogenic organisms with an increasing incidence in humans. Infectious diseases with increased incidence over the past two decades or those which threaten to increase in the near future are considered "emerging." Emerging infectious diseases include pathogens which are newly evolving, spreading to new geographic areas, are previously unrecognized, or are old infections reemerging due to lapses in public health measures.

Fungi Single-celled or multicellular organisms which cause infections in healthy persons or serve as opportunistic pathogens in persons who are immune compromised. Examples include histoplasmosis and aspergillosis.

Helminths Parasitic worms which live in humans or other animals and derive nourishment from their host. Examples include the tapeworm, fluke, or nematode.

Healthcare-Associated Infection (HAI) An adverse localized or systemic infectious condition occurring in a healthcare setting with no evidence that the infection was present at the time of admission.

Pathogen A biological organism capable of causing disease or illness to its host.

Prion The smallest infectious particle. It is an infectious strand of protein which replicates and leads to disease, and is similar to a virus. Prions are the causative agents of diseases such as mad cow disease and Creutzfeldt–Jakob disease.

Protozoa A single-celled parasitic organism that can only multiply inside a host organism.

R Nought (R_0) A metric widely used in assessing disease transmissibility or the basic reproductive rate. It represents the average number of subsequent cases which one case generates during its infectious period.

Rickettsia A group of microorganisms requiring other living cells for growth like viruses, but having cell walls, using oxygen, and having metabolic enzymes like bacteria. Rickettsia are typically transmitted by ticks, mites, or lice. Typhus is one example of a disease caused by rickettsia.

Virus An infectious organism consisting of a nucleic acid molecule in a protein coat. It is only able to multiply inside the living cells of a host.

Emerging Infectious Disease

Emerging infectious diseases (EIDs) are some of the most challenging public health issues facing the global community. The hypothesis of "disease emergence" may have helped shaped the growth of global health initiatives, particularly at the World Health Organization (Brown et al., 2005; Lakoff, 2010). EIDs are caused by pathogens that: (1) have increased in incidence, geographic, or host range; (2) have changed pathogenesis; (3) have newly evolved; or (4) have been discovered or newly recognized (Lederberg et al., 1992).

In most developed countries, routine and seasonal outbreaks challenge health departments and healthcare systems, but reporting, investigation, and treatment protocols are typically in place, trained on, and easily implemented. Vaccination programs and antiviral and antimicrobial medications mitigate many recurring infectious disease risks.

Those who have been exposed to or infected with recurring illnesses have developed some immunity. However, novel infectious diseases pose challenges that often exceed the immune function of populations and the capabilities of public health systems around the world.

Factors Contributing to Emerging Infectious Diseases

There are several factors that permit infections previously not seen globally or in specific locations to emerge or reemerge after periods of quiescence. Those factors include:

- international travel and commerce
- economic development
- human demographic factors and behavior
- technology and industry
- microbial adaptation
- breakdown of public health measures and systems

International travel and commerce and the movement of goods and people permits the movement of sick people and disease vectors into areas previously not visited, thereby exposing others to pathogens previously not encountered. International tourism has expanded consistently for over 60 years. From 1950 to 1980 it grew more than ten-fold from 25 million in 1950 to 278 million in 1980. It nearly doubled again between 1980 to 1995 reaching 528 million and again by 2013 reaching 1.087 billion. Annual growth in tourism is expected to grow by over 3% each year reaching 1.8 billion international annual tourist arrivals in 2030 (UN, 2014). Modern transportation systems allow for rapid movement of people and with them diffusion of illness at a greater speed than during the preavia tion travel era. When travel was slower, often by caravan or ship, those who were ill could recover, layover, or succumb without transporting disease as easily.

Increased international travel is believed to have played a major role in the spread of HIV/AIDS. Some virologists suspect that HIV was present at very low levels in remote areas of West Africa for perhaps as long as 100 years in animals before the disease reached epidemic proportions and was officially isolated by scientists in 1983 (Krause). Hunting animals as a source of protein created greater exposure of humans to the disease, and development of the transcontinental highway from Point-Noire, Zaire (now the Democratic Republic of Congo) to Mombasa, Kenya, may have allowed truck drivers and traders along this route to carry the virus into the general population.

Airline travel has its own unique risks, with recirculated air in the confined space of an aircraft which could expose travelers to airborne diseases such as tuberculosis (see Fig. 10-4). Passenger compartment conditions have some similarities to the holds of ships in sea-crossings known historically for harboring EIDs. With the ease of global travel, people with increased luxury income can visit developing countries, exposing those populations to novel diseases, or return home with novel infections after several hours of airline travel and before signs or symptoms of illness become apparent.

FIGURE 10-4 CDC quarantine officer Danitza Tomianovic entering a plane in order to assess the status of an ill traveler at the Miami International Airport. This image was captured during an October 2008 preparedness exercise. *Photo by Christine Pearson courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Economic development may result in changes of land use from agriculture to industry, disrupting established ecosystems. Altering natural habitats by building dams and creating deforestation–reforestation programs alters the balance of ecosystems, allowing some species to overflourish or die out. Additionally, there may be movement of people into land previously occupied by vegetation and animals, exposing those who resettle to novel or previously contained pathogens and/or vectors. Zoonotic diseases, those which infect animals, comprise 60–75% of EIDs (Taylor et al., 2001). In *The Coming Plague: Newly Emerging Diseases in a World out of Balance*, medical journalist Laurie Garret writes "In this fluid complexity, human beings stomp about with swagger, elbowing their way without concern into one ecosphere after another (Garrett, 1994)." In addition, the effect of climate change on emerging diseases is unknown; however, Lindgren et al. (2012) point out that climate change interacts with "a complex web" of all drivers of emerging diseases and therefore cannot be ignored. Alterations of the geographic ranges of birds in Europe and North America have also been demonstrated. Many migrating birds carry pathogens, and changes to migratory bird habitats may result in human exposures to new pathogens (Fuller et al., 2012). Climate change may also have effects on vector development, vector physiology, and vector habitat, ultimately affecting human vector-borne disease risks (Parham et al., 2015).

Human demographic factors and behavior including population density, population growth, and population distribution not only may affect the spread of people into geographic regions not previously inhabited, but it also can expose them to new pathogens. In addition, it may affect how disease transmission occurs from human to human. In many parts of the world, an increase in urban population is not matched by an increase in urban infrastructure and is accompanied by poverty, poor sanitation, and inadequate housing. Conflict can result in population shifts to new geographic areas, disruption of critical infrastructure (including public health and health systems), and economic stress. Poverty from any cause not only affects sanitation and vector control, but may force people into risk behaviors such as entering the sex trade. Once ill, people living in poverty may not have access to healthcare or even have basic hygiene resources. They also may be unable to comply with isolation measures. As populations continue to age and advanced medical interventions such as chemotherapy and immunosuppressive biologicals alter immune function, diseases previously not known to infect humans can emerge. Behaviors such as sexual activity and illicit drug use may also impact novel disease transmission.

FIGURE 10-5 In some countries, cultural practices prohibit euthanasia of unwanted, diseased, and aggressive animals. Ineffective control measures result in overcrowding, unsanitary conditions, death, and disease. *Photo by Ryan M. Wallace, DVM, MPH, courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Understanding human relationships with animals provides additional insights into EID risks (see Fig. 10-5). Sixty percent of recent emerging diseases are zoonotic. Colocation of open poultry markets and cohabitation with poultry has been identified as an important risk factor for human cases of avian influenza (Dinh et al., 2006; Thorson et al., 2006; Choi et al., 2005). Human cases of high pathogenic avian influenza have occurred in workers depopulating flocks in the Netherlands and Canada (Koopmans et al., 2004; Tweed et al., 2004). Fortunately, few of these outbreaks to date have sustained human-to-human transmission. In 2003, an investigation of a large multistate outbreak of monkeypox was traced back to prairie dogs sold as exotic pets. The prairie dogs had been in close contact with giant Gambian rats from Ghana (CDC, 2003a). This outbreak resulted in increased controls of imported exotic animals and markets. The source of the 2003 severe acute respiratory syndrome (SARS) outbreak has never clearly been identified. The index cases were initially linked to catlike exotic pets related to raccoons called “civet cats” (CDC, 2003b).

This resulted in extensive bans on civet cat transportation and commerce. However, detailed investigation links the causative coronavirus to several wild animals used as food, and there are suggestions that the trade of many types of animals used in food was the source (CDC, 2003a,b; He, 2003a,b; Normille and Enserink, 2003; Guan et al., 2003; Ng, 2003).

Bats play an important role in ecosystems in vector control, seed dispersal, and pollination. However, it is increasingly recognized that bats also play a significant role in the reservoir and transmission of zoonotic infections. Contact with bats has long been recognized as a potential source for rabies, but several findings indicate that bats have a wider spectrum of diseases and may be a reservoir for paramyxoviruses such as measles, mumps, distemper, parainfluenza (Drexler et al., 2012; Messenger et al., 2003), and Ebola (Leroy et al., 2007). Freidl et al. (2015) recently discovered antibodies for influenza A H9 in bats. Influenza A H9 is a zoonotic disease and is a possible candidate for a novel pandemic strain. Human interactions with bats and their habitats can occur in the workplace, home or recreational venues. In an observational study in western Ghana, nearly half of the residents had contact with bats and bat habitats (Anti et al., 2015). Reengineering and reopening closed facilities where bats have populated must be made with prevention methods in place. Entering caves where bats and other animals live must also be approached with infectious disease precautions in mind.

Technology and industry certainly have tremendous human benefits but may also expose populations to conditions which foster EIDs. Some of the most significant issues are changes in food production. Mass agricultural compounds and facilities create environments where changes occur in microbial ecology. Globalization of the food supply allows transportation of organisms on and in food and through accompanying vectors. Food transportation over large distances may also introduce breaches in food security.

Advances in medical technology introduce techniques that allow bacteria to infect people and spaces not formerly at risk. Increases in invasive procedures can result in the introduction of novel organisms.

FDA discovers fungus in steroid shots, meningitis toll increases to 20 in U.S.

Reuters News, October 19, 2012

An epidemiological investigation in 2012 traced the source of a mysterious meningitis outbreak to contamination of methylprednisolone acetate, a steroid injected to relieve back pain. Several lots of the drug were contaminated with a rare fungus called *Exserohilum rostratum*. Over 13,000 patients were potentially exposed and 749 had confirmed infections, resulting in 61 deaths across 20 states (Smith et al., 2013).

The CDC healthcare-associated infection (HAI) 2011 survey of a large sampling of US acute care hospitals found on any given day, about 1 in 25 hospital patients has at least one HAI (see Table 10-1). There were an estimated 722,000 HAIs in US acute care hospitals in 2011, and about 75,000 patients died during their hospitalizations. More than half of all HAIs occurred outside of the intensive care unit.

Table 10-1 Estimated 2011 US Healthcare-Associated Acute Care Hospital Infections

Major Infection Site	Estimated Cases
Pneumonia	157,500
Gastrointestinal illness	123,100
Urinary tract infections	93,300
Primary bloodstream infections	71,900
Surgical site infections from any inpatient surgery	157,500
Other types of infections	118,500
Estimated total number of infections in US hospitals	**721,800**

To read the full report, please visit the CDC HAI Prevalence Survey (Magill et al., 2014).

Contaminated gastrointestinal and bronchoscopy endoscopic devices are among the many advanced technologies associated with increasing outbreaks in healthcare settings, including those of organisms such as *Pseudomonas aeruginosa* and *Salmonella* spp. (Kovalevaa et al., 2013). The US Food and Drug Administration, whose responsibilities include medical devices, issued a warning in March of 2015 raising awareness that several devices with complex designs may be difficult to adequately clean. Many causative agents of healthcare associated infections are especially dangerous but their transmission is preventable. While some causative agents are more common bacteria and viruses such as *Escherichia coli* or norovirus, many are less common, including *Acinetobacter*, *Burkholderia*, *Clostridium*, and *Klebsiella*. In addition, antibiotic-resistant strains such as carbapenem-resistant *Enterobacteriaceae*, methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococci* and *S. aureus* are more difficult to control and treat. After the establishment of the European Union in the 1990s and increased economic growth, patient transfer within and between countries expanded. After political changes and the opening of borders, medical care and technology improved. For example, the number of bone-marrow transplant units in central Europe increased from 9 to 85 by 1995, and the number of dialysis units increased from approximately 200 to more than 1500 (Krcmery, 1997). However, Vincent et al. (1995) reported in a one-day prevalence study that 21% of ICU patients in Western Europe had nosocomial or healthcare-associated infections by microorganisms including *P. aeruginosa* and methicillin-resistant *Staphylococcus*.

Microbial adaptation contributes to the development of "super-bugs." This includes both bacteria and viruses (see Figs. 10-6 and 10-7). As discussed in the previous section, antimicrobial resistance is pervasive and is increasing in the face of widespread overuse and misuse of antibiotics. In addition, viruses rapidly adapt to immunologic responses. Influenza viruses provide an example of genetic drift and shift which make them a persistent health threat. Once formed, novel influenza viruses sometimes pose health risks for which humans and/or animals have little to no immunologic protection. These viruses can also develop an increased capacity for animal-to-animal or human-to-human sustained transmission.

Breakdown in public health systems and measures as a result of conflict, economic-based program cuts, or poor infrastructure can produce environments with increased risk and decreased prevention. This situation may result in disease emergence, but may also

FIGURE 10-6 A scanning electron micrograph image of two rod-shaped carbapenem-resistant *Klebsiella pneumoniae* bacteria interacting with a human white blood cell known specifically as a neutrophil. *Photo courtesy of the National Institute of Allergy and Infectious Diseases.*

FIGURE 10-7 CDC microbiologist Valerie Albrecht holding up for observation two Petri dish culture plates that were inoculated with methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria. *Photo by Melissa Dankel courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

result in reemergence of diseases. Diseases which had previously been controlled through sanitation, vector control, or vaccination programs can reemerge if any of the prevention programs fail or stop. In developed countries with successful vaccination campaigns, many diseases have been declared "controlled" or "eradicated." Because of this, political and

public interest in continued vaccination programs is waning, or personal risk is considered low relative to the risk (real or perceived) of vaccinations. In the United States there are also many states allowing "opt-out" programs so people may choose not to get vaccinated or have their children vaccinated. In numerous outbreaks this has proved problematic.

Measles Cases Linked to Disneyland Rise, and Debate Over Vaccinations Intensifies

The US antivaccination movement has contributed to increased preventable illnesses and deaths. It is led by misguided conspiracy theorists, minor celebrities, and a small number of "healthcare professionals" who are either unfamiliar with or in denial of the science supporting vaccinations. The above headline appeared in January 2015 in the *New York Times* (Nagourney and Goodnough, 2015). Notable quotes from this report include:

- "We can expect to see many more cases of this preventable disease unless people take measures to prevent it," Dr. Gilberto F. Chavez, the deputy director of the California Center for Infectious Diseases, said. "I am asking unvaccinated Californians to consider getting vaccinated against measles."
- Dr. James Cherry, a specialist in pediatric infectious diseases at UCLA, said the outbreak was "100 percent connected" to the anti-immunization campaign. "It would not have happened otherwise—it would not have gone anywhere," he said. "There are some pretty dumb people out there."
- "The problem is that there are these pockets with low vaccination rates," said Dr. Jane Seward, deputy director of the viral diseases division at the CDC. "If a case comes into a population where a lot of people are unvaccinated, that's where you get the outbreak and where you get the spread."

In Ghent, Belgium, a 2011 measles outbreak was associated with an anthroposophic school which promotes "complementary medicine" (Braeye et al., 2013). Over 65 cases of measles were identified in a school that had low vaccination rates because of the philosophical beliefs of the parents. Leaders of the school were not against vaccination. Striking the balance between individual rights and beliefs, relative risk perception and acceptance, and public health priorities is always challenging.

Likely Sources for Emerging Infectious Diseases

While the next emerging disease can be of any species of infectious organism, trends in recent cases display patterns suggesting which threats may be imminent (See Table 10-2). Coronaviruses such as the causative agents of SARS and Middle East Respiratory Syndrome Co-V (MERS Co-V); filoviruses such as Ebola; and novel influenza viruses, are considered likely candidates. In a study by Taylor et al., 2001 an analysis of emerging species revealed that of those known, there are 175 currently emerging species. Viruses and prions are less than half of the total (44%), and bacteria or rickettsia comprise just under one-third. These

Table 10-2 Emerging Species in Each Major Taxonomic Division

Taxonomic Division	% of Emerging Diseases
Viruses or prions	44
Bacteria or rickettsia	30
Protozoa	11
Fungi	9
Helminths	6

Adapted from Taylor, L.H., Latham, S.M., Woolhouse, M.E., 2001. Risk factors for human disease emergence. Philos. Trans. R. Soc. B Biol. Sci. 356 (1411), 983–989.

potential pathogens may be transmitted by several routes, and the most common route is direct contact (53%), followed by indirect contact (47%), vectors (28%), and for 6% the route of transmission is unknown (Taylor et al., 2001).

Prevention and Preparedness

While it may not be possible to predict which pathogens may emerge or reemerge, it is possible to build infrastructure and take general steps to make populations and public health systems better prepared for the next novel infectious disease outbreak. At the heart of these measures is epidemiological surveillance. Identification of a new illness or disease requires surveillance systems which not only continually monitor "routine" illness, but also have the ability to recognize anomalies when something is not "routine." As described in chapter "Bioterrorism," there have been extensive efforts toward developing early warning epidemiological and environmental surveillance systems for unusual diseases and pathogens. The vital link in identifying a novel disease in a community is the astute clinician. Clinicians must be able to recognize a novel disease, report it appropriately, and feel confident that the information will be quickly analyzed and acted upon. Laboratory support is vital to quickly identifying and characterizing an emerging threat. This includes testing for drug resistance to inform decision-making concerning appropriate medical countermeasures. Continued epidemiological surveillance throughout an outbreak can produce data which may be useful in evaluating and improving the public health and medical response.

Preparedness Actions for Emerging Infectious Disease

- surveillance
- robust outbreak investigation practices
- transmission prevention through containment and control measures
- delivery of medical countermeasures, if any
- public messaging
- recovery to a "new normal"

FIGURE 10-8 Hasan Alkaf, DVM, is shown extracting blood samples from a camel's neck during the investigation into the first reported Middle East Respiratory Syndrome Coronavirus (MERS-CoV) case in Haramout, Yemen. *Photo by Awadh Mohammed Ba Saleh, Yemen, courtesy of the Centers for Disease Control and Prevention, Public Health Image Library.*

Along with surveillance is the ability of public health responders to perform detailed outbreak investigations to determine the characteristics of the disease. Characterization of the outbreak, identifying the natural course of the illness, and recognizing key risks for infection are necessary in order to learn how the new illness behaves in a population (see Fig. 10-8). This information will also inform control measure decisions. A priority item in the initial characterization of an outbreak is the identification of transmissibility. Unfortunately, as surveillance methods are enhanced and cases are increasingly recognized and reported, transmissibility may be a very difficult thing to quantify. For example, the current analyses of transmissibility for MERS Co-V suggest that it is not a likely pandemic threat because of its low reproduction number or "r nought" (R_0). However, different cluster sizes, demographics, geographies, and public health and healthcare infrastructures may alter the outbreak characteristics and the reproduction number (R_0) (Fisman et al., 2014). Capturing critical data will allow for accurate characterization within the context of the outbreak and will direct response activities such as control measures and medical surge management.

Response and Recovery

The primary control strategy in all infectious disease outbreaks is preventing transmission. Even minimal biosecurity actions can prevent animal-to-human transmission. Separation of potential source animals, such as exotic imported animals and poultry, from routines such as cooking can reduce risk. Effective cleaning of animal waste and habitats should be performed with at least basic respiratory protection. To prevent human-to-human transmission, good hygiene practices such as hand washing, general surface cleaning,

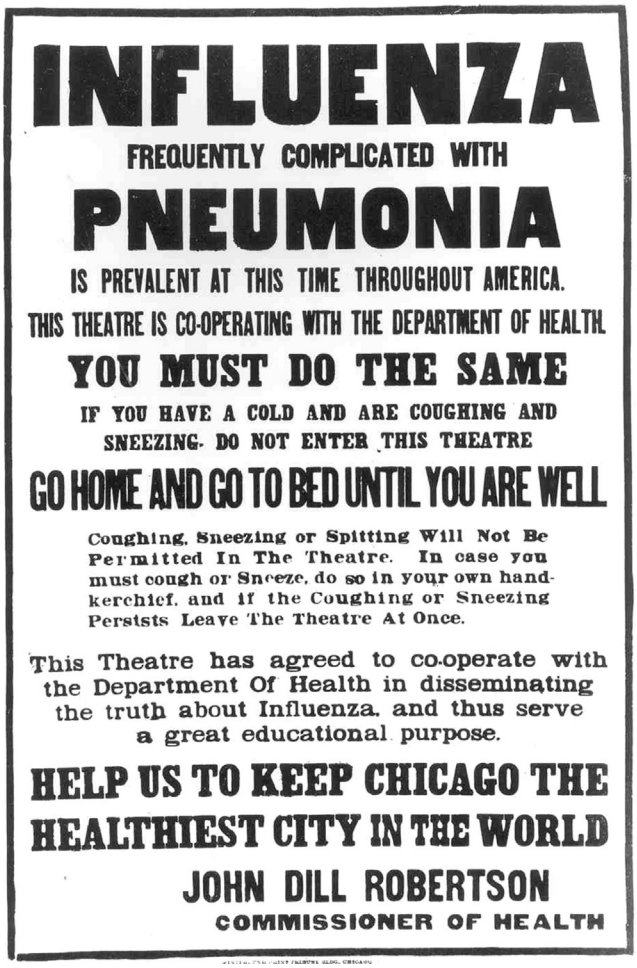

FIGURE 10-9 Influenza warning posters, then and now: Chicago Department of Health poster from the early 20th Century warned those who were ill to stay away from theaters and other public places. *Photo courtesy of the Department of Health and Human Services, Office of the Public Health Service Historian.*

and careful waste disposal should be reinforced. During the 2009–2010 H1N1 pandemic, people were advised to "cough hygienically" into their sleeve to prevent contamination of the hands and then others. Of note, this technique was not without some controversy and was not recommended in the United Kingdom and Spain (Anderson, 2010). Supplying hand wipes and hand sanitizer may be implemented in some locations of businesses, critical industries, and government agencies where other measures may not be reasonable. Social distancing by school closures, limiting mass gatherings, and canceling large events may be necessary (see Figs. 10-9 and 10-10). Quarantine may be considered for individuals who have been exposed but are not yet sick, typically for two incubation periods of the disease. Isolation separates those who are already ill from those who are not ill.

FIGURE 10-10 Influenza warning posters, then and now: New York State poster encouraging patients arriving to hospitals to identify themselves if they have flu-like symptoms. *Image courtesy of the New York State Department of Health.*

In healthcare settings, isolation may begin from early screening of patients at points of entry. This may limit disease transmission to other patients who often have underlying conditions which increase their risks for severe illnesses and complications. Risk management for communicable diseases in emergency departments includes signage to encourage patients to self-identify if they are sick or have an associated travel history. This allows for rapid triage to isolation areas and early institution of personal protective equipment for staff (Puro et al., 2008).

In a 2012 study conducted of 41 facilities in 14 European countries, 83% had isolation rooms, but not all had anterooms, negative pressure, or HEPA filtration. Only 14.6% had

all components. Personnel trained in the recognition of highly infectious diseases were available in 24 of the 41, and management protocols were available in 35 of the 41 (Fusco et al., 2012). It would be interesting to see how attention paid to diseases such as Ebola has impacted these numbers.

In addition to human-to-human spread, animal-to-human spread is a common transmission route for EIDs. Zoonotic disease professionals can develop recommendations for vector control when zoonotic diseases threaten human populations. Mosquitoes are the most pervasive disease-carrying vectors. Control measures include reducing standing water breeding sources or using larvicides and adulticides. The recent introduction of engineered *Aedes aegypti* mosquitoes (OX513A), which can reproduce and produce offspring which die rapidly, shows promise in areas with emerging dengue fever (Specter, 2012).

Once control measures are determined, public health agencies must have the legal and social authority to implement recommended measures. The majority of the population typically complies with basic containment measures such as improved hygiene, avoiding ill people, etc. However, some individuals may be reluctant or unable to comply. For example, minimally ill people without paid sick leave may not be able to stay at home without significant economic loss. People may, out of fear, choose to flee quarantine zones. In these cases, agencies need to have flexible, scalable authorities to limit travel outside areas known to have disease. The challenges with quarantine measures were apparent throughout the international response to the 2014–2015 West African Ebola epidemic. In the United States as in many countries, the government has the authority to restrict state-to-state and international travel. State and local health agencies have authority to control intrastate activities. However, political pressure may make it difficult to enact some control measures. School closure is one of the more difficult decisions for government agencies during a public health emergency. For many communicable diseases, children can act as superspreaders because of their behaviors and hygiene lapses. However, many schools function not only as places of education but also deliver significant social programs: safe havens, meals, and day care for working parents with marginal income. To close these schools disrupts very necessary social welfare programs.

Quarantine laws must also respect civil liberties. In the United States for example, quarantine orders must be the least restrictive form of control, have very clear reasons, be time-limited and allow for appeal. Enforcement of quarantine orders requires law enforcement officers to interact, sometimes in close physical proximity, with potentially contagious individuals. Additionally, any enforcement of quarantine of an individual must be heard in the judicial system. The judiciary has its own constitutional constraints of process which are frequently in opposition to the goals of quarantine.

If the EID is susceptible to antibiotics or a vaccine is quickly developed, rapid distribution and dispensing of these medical countermeasures must be conducted. If the illness is highly contagious, programs limiting public interaction during mass dispensing and mass vaccinations will need to be implemented. As discussed throughout this text, it is unlikely that there will be large quantities of medical countermeasures available early on in an

emerging or reemerging infectious disease outbreak. Therefore, plans must also be in place for the utilization of scarce resources while complying with ethical and legal frameworks.

Throughout the entire outbreak, appropriate public messaging must be delivered. Messages will contain information about the illness, personal protective actions, and where to go for health care. These messages must communicate risk and how individuals can limit morbidity and mortality. General prescripted public health messages can often be adapted early in an outbreak when detailed information on the threat is not yet specific. Trusted leaders in the community should be used to deliver messages in order to improve compliance and alleviate fear.

A "new normal" may follow as a community recovers from a novel outbreak. Some EIDs become endemic diseases in affected communities and must be included in recurring public health activities. For example, West Nile virus was first introduced to the Western Hemisphere in the late 1990s and is now an annual threat, causing 41,762 cases from 1999 to 2014 and 1765 deaths (CDC, 2014). However, public health responses help to establish new practices in order to limit reemergence. These activities also prepare the community for similar EID threats. Because of ongoing West Nile virus threats in North America, the region is better prepared for emerging threats such as chikungunya and dengue.

Conclusion

Public health has been challenged with EIDs throughout human history. With globalization of populations, commerce, and travel comes globalization of infectious diseases. This exposes people and animals to novel diseases for which they have little to no natural immunity. Rapid transportation and free movement allows sick individuals to spread illness and disease faster than ever before. Preparedness efforts cannot predict the next emerging infection, but public health and healthcare capabilities developed, lessons learned from prior outbreaks, and institutionalization of routine infection control practices may serve to lessen the impact.

Websites

Centers for Disease Control and Prevention (CDC), Healthcare-Associated Infections (HAI). http://www.cdc.gov/hai/.

Centers for Disease Control and Prevention, The 2009 H1N1 Pandemic: Summary Highlights, April 2009–2010: http://www.cdc.gov/h1n1flu/cdcresponse.htm.

Centers for Disease Control and Prevention (CDC), Division of Global Health Protection (DGHP). http://www.cdc.gov/globalhealth/healthprotection/default.htm.

Centers for Disease Control and Prevention (CDC), National Center for Infectious Diseases (NCID), Emerging Infectious Diseases. http://www.cdc.gov/ncidod/diseases/eid/index.htm.

Emerging Infections Network (EINet), University of Washington. http://depts.washington.edu/einet/.

Food and Drug Administration, FDA and CDC Public Health Advisory: Infections from Endoscopes Inadequately Reprocessed by an Automated Endoscope Reprocessing System. http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/PublicHealthNotifications/ucm062282.htm.

State University of New York Levin Institute, Globalization 101. http://www.globalization101.org.

University of Washington, Emerging Infections of International Public Health Importance, On-line Course. http://depts.washington.edu/eminf/.

World Health Organization, West Nile Virus Fact Sheet. http://www.who.int/mediacentre/factsheets/fs354/en/.

World Health Organization, Ebola Situation Reports. http://apps.who.int/ebola/ebola-situation-reports.

World Health Organization, Emergencies Preparedness, Response. http://www.who.int/csr/en/.

References

Andersen, B.M., May 2010. European Centre for disease prevention and control swine flu guidelines: 'cough hygienically' into your sleeve? J. Hosp. Infect. . ISSN: 0195-6701 75 (1), 73–74. http://www.sciencedirect.com/science/article/pii/S0195670110000265.

Anti, P., Owusu, M., Agbenyega, O., Annan, A., Badu, E.K., Nkrumah, E.E., Tschapka, M., Oppong, S., Adu-Sarkodie, Y., Drosten, C., 2015. Human–bat interactions in rural West Africa. Emerg. Infect. Dis. 21 (8), 1418–1421. http://dx.doi.org/10.3201/eid2108.142015.

Braeye, Y., Sabbe, M., Hutse, V., Flipse, W., Godderis, L., Top, G., 2013. Obstacles in measles elimination: an in-depth description of a measles outbreak in Ghent, Belgium, spring 2011. Arch. Public Health 71, 17. http://dx.doi.org/10.1186/0778-7367-71-17.

Brown, T., Fee, E., Cuerto, M., 2005. The world health organization and the transition from international to global public health. AJPH 95 (1), 62–72.

Centers for Disease Control and Prevention (CDC), 2001. Outbreak of Ebola Hemorrhagic Fever--Uganda, August 2000-January 2001. MMWR Morb Mortal Wkly Rep. February 09, 2001, 50 (05), 73–67. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5005a1.htm.

Centers for Disease Control and Prevention (CDC), 2003a. Update: multistate outbreak of monkeypox – Illinois, Indiana, Kansas, Missouri, Ohio, and Wisconsin, 2003. MMWR. 52 (27), 642–646. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5227a5.htm.

Centers for Disease Control and Prevention (CDC), 2003b. Prevalence of IgG antibody to SARS-associated coronavirus in animal traders – Guangdong province, China, 2003. MMWR. 52 (41), 986–987. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5241a2.htm.

Centers for Disease Control and Prevention (CDC), 2014. West Nile Virus, Final Cumulative Maps & Data for 1999–2014. http://www.cdc.gov/westnile/statsmaps/cummapsdata.html.

Centers for Disease Control and Prevention (CDC), 2015. 2014 Ebola Outbreak in West Africa - Case Counts. http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/case-counts.html.

Choi, Y.K., Seo, S.H., Kim, J.A., Webby, R.J., Webster, R.G., February 20, 2005. Avian influenza viruses in Korean live poultry markets and their pathogenic potential. Virology. ISSN: 0042-6822 332 (2), 529–537. http://www.sciencedirect.com/science/article/pii/S0042682204008165.

Dinh, P.N., Long, H.T., Tien, N.T.K., et al., 2006. Risk factors for human infection with avian influenza a H5N1, Vietnam, 2004. Emerg. Infect. Dis. 12 (12), 1841–1847. http://dx.doi.org/10.3201/eid1212.060829.

Drexler, J.F., Corman, V.M., Müller, M.A., Maganga, G.D., Vallo, P., Binger, T., Drosten, C., 2012. Bats host major mammalian paramyxoviruses. Nat. Commun. 3, 796. http://dx.doi.org/10.1038/ncomms1796.

Fisman, D.N., Leung, G.M., Lipsitch, M., 2014. Nuanced risk assessment for emerging infectious diseases. Lancet. 383 (9913), 189–190. http://dx.doi.org/10.1016/S0140-6736(13)62123-6.

Freidl, G.S., Binger, T., Müller, M.A., de Bruin, E., van Beek, J., Corman, V.M., Koopmans, M., 2015. Serological evidence of influenza a viruses in frugivorous bats from Africa. PLoS One 10 (5), 1–7. http://dx.doi.org/10.1371/journal.pone.0127035.

Fuller, T., Bensch, S., Muller, I., Novembre, J., Perez-Tris, J., Ricklefs, R.E., Smith, T.B., Waldenstrom, J., March 2012. The ecology of emerging infectious diseases in migratory birds: an assessment of the role of climate change and priorities for future research. EcoHealth 9 (1), 80–88.

Fusco, F.F., Schilling, S., DeIaco, G., Brodt, H.-R., Brouqui, P., Maltezou, H.S., Bannister, B., Gottschalk, R., Thomson, G., Puro, V., Ippolito, G., EuroNHID Working Group, 2012. Infection control management of patients with suspected highly infectious diseases in emergency departments: data from a survey in 41 facilities in 14 European countries. BMC Infect. Dis. 12, 27. http://www.biomedcentral.com/1471-2334/12/27.

Garrett, L., 1994. The Coming Plague: Newly Emerging Diseases in a World Out of Balance. pp. 618–619 New York: Farrar, Straus and Giroux.

Gatherer, D., July 2009. The 2009 H1N1 influenza outbreak in its historical context. J. Clin. Virol. ISSN: 1386-6532 45 (3), 174–178. http://www.sciencedirect.com/science/article/pii/S1386653209002534.

Guan, Y., Zheng, B.J., He, Y.Q., et al., 2003. Isolation and characterization of viruses related to the SARS coronavirus from animals in southern China. Science 302 (5643), 276–278.

He, S.F., et al., 2003a. Severe acute respiratory syndrome in Guangdong province of China: epidemiology and control measures. Chin. J. Prev. Med. 37 (4), 227.

He, S.F., et al., 2003b. An epidemiological study on the index cases of severe acute respiratory syndrome occurred in different cities in Guangdong province. Chin. J. Epidemiol. 24 (5), 347.

Johnston, L., Conly, J.M., July–August 2000. West Nile virus – where did it come from and where might it go? Can. J. Infect. Dis. 11 (4), 175–178. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2094770/#B27.

King, N.B., 2004. The scale politics of emerging diseases. The history of science society. OSIRIS 19, 062–076.

Koopmans, M., Wilbrink, B., Conyn, M., Natrop, G., van der Nat, H., Vennema, H., Meijer, A., van Steenbergen, J., Fouchier, R., Osterhaus, A., Bosman, A., February 21, 2004. Transmission of H7N7 avian influenza A virus to human beings during a large outbreak in commercial poultry farms in the Netherlands. Lancet. ISSN: 0140-6736 363 (9409), 587–593. http://dx.doi.org/10.1016/S0140-6736(04)15589-X.

Kovalevaa, J., Peters, F.T.M., van der Mei, H.C., Degener, J.E., April 2013. Transmission of infection by flexible gastrointestinal endoscopy and bronchoscopy. Clin. Microbiol. Rev. 26 (2), 231–254.

Krcmery, V., 1997. Trends in nosocomial infections in europe: comparison between Western and Central Europe. J. Clin. Microbiol. Infect. 3 (7), 18.

Lakoff, A., 2010. Two regimes of global health. Humanity 1 (1), 59–79.

Lederberg, J., et al. (Ed.), 1992. Emerging Infections: Microbial Threats to Health in the United States. Institute of Medicine, National Academy Press.

Leroy, E.M., Epelboin, A., Mondonge, V., Pourrut, X., Gonzalez, J.-P., Muyembe-Tamfum, J.-J., Formenty, P., 2007. Human ebola outbreak resulting from direct exposure to fruit bats in Luebo, Democratic Republic of Congo, 2007. Vector Borne Zoonotic Dis. 9 (6), 723–728.

Lindgren, E., Andersson, Y., Suk, J.E., Sudre, B., Semenza, J.S., April 2012. Monitoring EU emerging infectious disease risk due to climate change. Science 336 (6080), 418–419. http://dx.doi.org/10.1126/science.1215735.

Magill, S.S., Edwards, J.R., Bamberg, W., et al., 2014. Multistate point-prevalence survey of health care–associated infections. N. Engl. J. Med. 370, 1198–1208.

Messenger, S.L., Rupprecht, C., Smith, C., 2003. Bats, emerging virus infections and the rabies paradigm. In: Kunz, T.H., Fenton, M.B. (Eds.), Bat Ecology. University of Chicago Press, Chicago, pp. 622–679.

Nagourney, A., Goodnough, A., January 21, 2015. Measles Cases Linked to Disneyland Rise, and Debate Over Vaccinations Intensifies. New York Times. http://www.nytimes.com/2015/01/22/us/measles-cases-linked-to-disneyland-rise-and-debate-over-vaccinations-intensifies.html.

Normille, D., Enserink, M., 2003. Tracking the roots of a killer. Science 301, 297–299.

Ng, S.K.C., 2003. Possible role of an animal vector in the SARS outbreak at Amoy Gardens. Lancet 362, 570–572.

Parham, P.E., Waldock, J., Christophides, G.K., Hemming, D., Agusto, F., Evens, K.J., Fefferman, N., Gaff, H., Gumel, A., Ladeau, S., Lenhart, S., Mickens, R.E., Naumova, E.N., Ostfeld, R.S., Ready, P.D., Thomas, M.B., Velasco-Herandez, J., Michael, E., February 16, 2015. Climate, environmental and socio-economic change: weighing up the balance in vector-borne disease transmission. Phil. Trans. R. Soc. B 370. http://dx.doi.org/10.1098/rstb.2013.0551. 20130551.

Puro, V., Fusco, F.M., Lanini, S., Nisii, C., Ippolito, G., 2008. Risk management of febrile respiratory illness in emergency departments. New Microbiol. 31, 165–173.

Roehrig, J.T., 2013. West Nile virus in the United States-a historical perspective. Viruses 5 (12), 3088–3108. http://dx.doi.org/10.3390/v5123088.

Smith, R.M., Schaefer, M.K., Kainer, M.A., Wise, M., Finks, J., et al., October 24, 2013. Fungal infections associated with contaminated methylprednisolone injections. N. Engl. J. Med. 369 (17), 1598–1609.

Specter, M., July 9, 2012. The Mosquito Solution. New Yorker Magazine. http://www.newyorker.com/magazine/2012/07/09/the-mosquito-solution.

Taylor, L.H., Latham, S.M., Woolhouse, M.E., July 29, 2001. Risk factors for human disease emergence. Philos. Trans. R. Soc. Lond. B Biol. Sci. 356 (1411), 983–989.

Thorson, A., Petzold, M., Chuc, N., Ekdahl, K., 2006. Is exposure to sick or dead poultry associated with flu-like illness? A population-based study from a rural area in Vietnam with outbreaks of highly pathogenic avian influenza. Arch. Intern. Med. 166 (1), 119–123. http://dx.doi.org/10.1001/archinte.166.1.119.

Tweed, S.A., Skowronski, D.M., David, S.T., Larder, A., Petric, M., Lees, W., Li, Y., Katz, J., Krajden, M., Tellier, R., Halpert, C., Hirst, M., Astell, C., Lawrence, D., Mak, A., 2004. Human illness from avian influenza H7N3, British Columbia. Emerg. Infect. Dis. 10 (12), 2196–2199. http://dx.doi.org/10.3201/eid1012.040961.

United Nations (UN), 2014. World Tourism Organization. UNWTO Tourism Highlights. Edition. http://www.e-unwto.org/doi/pdf/10.18111/9789284416226.

Vincent, J., Bihari, D.J., Suter, P.M., et al., 1995. The prevalence of nosocomial infection in intensive care units in Europe: results of the European prevalence of infection in intensive care (EPIC) study. JAMA 274 (8), 639–644. http://dx.doi.org/10.1001/jama.1995.03530080055041.

World Health Organization (WHO), 2014. Ebola response team 2014. Ebola virus disease in West Africa—the first 9 months of the epidemic and forward projections. N. Engl. J. Med. 371, 1481–1495.

World Health Organization (WHO), 2011. West Nile Virus Fact Sheet. http://www.who.int/mediacentre/factsheets/fs354/en/.

11

Floods

OBJECTIVES

- Describe the differences among various types of floods.
- Recognize flood warnings and watches.
- Describe the human factors that contribute to flooding.
- List the meteorological and topographical factors that contribute to flooding.
- Describe flood-related morbidity and mortality.
- Explain the differences between flood-related morbidity and mortality at various flood phases.
- Explain which populations are at greatest risk during a flood and why.
- List key public messages that should be shared during a flood.
- Describe immediate actions which can reduce health and safety risks during a flood.
- List major risks associated with postflood recovery and how these risks can be reduced.

Introduction: Common Issues of the 1988 Khartoum, Sudan Flood and the 2005 Post-Katrina Flooding of New Orleans

It is the capital city of Sudan and home to several million residents. The name of the city, Khartoum, means "elephant trunk" and is likely derived from the shape of the peninsula where the city is located at the confluence of the White and Blue Nile Rivers (DOS, 2015). The location is also prone to flooding. Throughout the 20th century, the city experienced a surge in population growth and urbanization. Weather pattern changes increased the frequency of area rainstorms, and changes in irrigation practices reshaped the terrain (Walsh et al., 1994). Although these factors can be managed by local officials to reduce the growing risk of flood, there was little planning prior to 1988 to prepare the population for the coming disaster. It has been suggested that the primary condition for reducing future flood risks in Khartoum is overcoming complacency and taking sensible measures to control the risks (Davies and Walsh, 1997).

In early August 1988, heavy rains fell on Khartoum. The rainfall exceeded the total annual rainfall amounts for the region on a single day more than once during that time-frame. By mid-August, over 100,000 homes had been destroyed, displacing over a million people. Making matters worse, thousands of refugees from civil conflicts in the nation had settled in low-lying flood-prone areas around the city. The Sudanese Ministry of Health received assistance from the World Health Organization and a variety of public and private health organizations around the world to mobilize surveillance activities for monitoring

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the health status of the population. Gathering information from dozens of clinics and several large hospitals, illness trends were tracked. Diarrheal disease was observed in nearly one-third of those seeking healthcare. Of more than 600 patients hospitalized for diarrhea, 68 died. The prevalence of malaria in the region doubled in the weeks following the flooding (CDC, 1989). The full health impact of this disaster will never be known. Most of those displaced by the flooding were refugees, and many illnesses and deaths among the refugee population were not investigated or reported.

Poor data collection on refugee populations in the region limits the availability of complete morbidity and mortality information from the Khartoum flood. However, it still provided valuable lessons. Existing gaps in local infrastructure, socioeconomic support, and public health resources in a community can be dramatically amplified by a flood. New diseases rarely emerge from floods. However, existing diseases not kept in check due to environmental, social, and physiological stress occurring during and after the disaster can increase infectious disease risks. Even as access to healthcare may be diminished, displaced populations living in austere conditions can be exposed to more disease-carrying vectors, experience poorer sanitation, and have limited access to safe food and water. This trend is repeated with many historical floods, including the flooding of New Orleans following Hurricane Katrina in 2005.

Even prior to Hurricane Katrina, New Orleans had serious challenges. The poverty rate of 23.2% was nearly twice the national average, and the vast majority of poor residents were African American (El Nasser, 2005). Much of the housing for poor residents was already in substandard condition before the hurricane and subsequent flooding from breached levees. The more expensive homes are built in areas that are typically safer and have better flood protection. More affluent residents also have the means to evacuate, whereas the low-income population and other vulnerable groups sometimes lack the means to protect themselves or evacuate. Following Hurricane Katrina, the death toll exceeded 1500 as people died at home or in areas they were evacuated to outside New Orleans (Hunter, 2006). Elderly and ailing individuals pulled from the floodwaters continued to succumb to their illnesses for weeks and months following evacuation. According to local mortuary records, 64% of those who perished in New Orleans were of age 65 and older (LA, 2006). Most died as a direct result of the flooding caused by the breached levees.

Like Khartoum, New Orleans had very clear flood risks but did little to carry out comprehensive planning prior to Hurricane Katrina and the associated flooding (see Fig. 11-1). Both cities had their most vulnerable populations in high-risk flood areas and lacked effective evacuation and emergency sheltering preparations. New Orleans certainly had “plans,” but plans are less useful if not part of an ongoing, dynamic planning process. Based on the response and outcomes, these processes were inadequate. In the end, lack of preparedness had the greatest impact on the most vulnerable populations of both cities.

FIGURE 11-1 New Orleans, Louisiana, September 8, 2005—FEMA's Urban Search and Rescue teams, en route by helicopter to conduct a search in St. Bernard Parish, view the flooding in New Orleans. *Federal Emergency Management Agency photo by Michael Rieger.*

Flood-Related Definitions

Acre-foot The volume of water which can cover 1 acre of land (43,560 square ft or 4047 square meters) with 1 foot of water. One acre-foot is equal to 325,851 gallons (1.2 million L).

Cubic feet per second (ft^3/s) A common unit of measurement used to describe water discharge. One cubic foot per second is equal to 448.8 gallons (1700 L) per minute.

Coastal flood warning A message issued by the National Weather Service when coastal flooding is occurring, imminent, or expected within 12 hours.

Coastal flood watch A message issued by the National Weather Service when coastal flooding is possible within 12–36 hours.

Discharge The rate of flow-volume of fluid passing a point per unit time, commonly expressed in cubic ft/meters per second, million gallons/liters per day, or gallons per minute.

Flash flood A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours, causing water to rise and fall rapidly. Flash floods are usually characterized by raging torrents after heavy rains rip through riverbeds, urban streets, or mountain canyons. Flash floods can also occur when no rain has fallen; for instance, after a levee or dam has failed, or after a sudden release of water by clearing of debris or an ice jam.

Flash flood watch A message indicating that flash flooding is possible. Be prepared to move to higher ground, and listen to NOAA weather warnings, a weather warning smartphone application, commercial radio, or television for information.

Flash flood warning A message indicating that a flash flood is occurring; seek higher ground on foot immediately.

Flood The excessive overflow of water onto normally dry land. The inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch. Ponding of water at or near the point where rain falls. Flooding is a longer-term event than flash flooding and can last for weeks.

Flood frequency Refers to a flood level with a specified percent chance of being equaled or exceeded in any given year. For example, a 100-year flood occurs on average once every 100 years and thus has a 1% chance of occurring in a given year.

Flood stage The stage at which overflow of the natural stream banks begins to cause damage within the area where the elevation is measured. Flood stages for each US Geological Survey (USGS) gauging station are usually provided by the National Weather Service.

Precipitation Rain, snow, hail, or sleet.

Surface runoff That part of the runoff traveling over the soil surface to the nearest stream channel. Surface runoff is also defined as the part of runoff from a drainage basin which has not passed beneath the ground surface.

Tsunami A large ocean wave caused by an underwater earthquake or volcanic eruption; often causes extreme destruction when it strikes land. Tsunami waves can be up to 98 ft (30 m) high and reach speeds of 589 mph (950 km/hour). They are characterized by long wavelengths of up to 124 miles (200 km) and long periods, usually between 10 and 60 minutes.

Floods

Floods are nature's most widespread disaster. In the last century, over eight million fatalities were attributed to floods (CRED, 2004). These disasters are growing in frequency worldwide due to a variety of human and environmental factors (see Table 11-1). The human factors contributing to flooding are mostly associated with development and land use. Expanding populations and urbanization along shorelines and waterways place more people in flood hazard areas. Most major cities are built near waterways that have historically provided a means for transportation, drinking water, and other urban necessities. As the environment near the water is altered, the flood risks are changed. Although some flood scenarios can be avoided through flood walls, levees, and other engineered solutions, the development and habitation of these historically flooded areas comes with risks.

Table 11-1 Factors Contributing to Flood Risks

Meteorological Factors	Human Factors	Topographical Factors
Precipitation	Floodplain habitation	Topography (slope)
• rainfall duration, amount, and intensity	Poor drainage infrastructure	Impermeable cover (urban areas)
• snow/snowmelt	Land use	Soil type and moisture
Temperature	• urbanization (sealing surfaces)	Vegetation
Wind	• deforestation	Ground surface permeation
Humidity	Overly efficient drainage upstream	Groundwater depth
Storm activity and direction	Climate change	Runoff patterns
Hurricanes/cyclones	Failed dams or levees	Ponds, lakes, and other basins that catch runoff
Season	Driving or wading in swift water	Bank and channel characteristics
		High tide drainage

In addition to the habitation of areas at risk, the alteration of the natural environment by human development contributes to new flood risks. When precipitation occurs in undeveloped areas, it saturates the soil and is absorbed by vegetation. When these processes meet their capacity, moisture accumulates in lower areas creating ponds, lakes, streams, and rivers. As people begin to inhabit an area, they remove much of the vegetation to cover the soil with buildings, roads, and other nonpermeable structures. This inevitably causes runoff challenges managed to some extent through storm drains, ditches, and culverts. However, the runoff from impermeable surfaces travels much faster than the runoff of natural terrains. This accumulated runoff speeds up even more when it enters a drainage system. This rapid buildup of fast-moving water poses a risk of urban flooding.

Dam and Levee Failure

Low-lying habituated areas near rivers are often protected by levee systems. Though they may be fairly effective, levees can create other problems. Residents across the river from a levee are flooded worse because the floodwaters that once spread over both sides of the river are pushed to only one side. Also, those residing inside or behind a levee may develop a false sense of security. Prior to the levee, those living in the floodplain would have had time to evacuate as the river slowly rose. With a levee system, there may be far less time to evacuate if a levee is breached. Levee breaks can create such destructive fast-rising waters that those living in a floodplain may be unable to escape. This was the case with the levee failures in New Orleans following Hurricane Katrina. Even frequent inspections of levee systems cannot guarantee safety. Levee damage is not always apparent. Seismic activity, extreme weather, and other factors can cause catastrophic levee damage and failure (see Fig. 11-2).

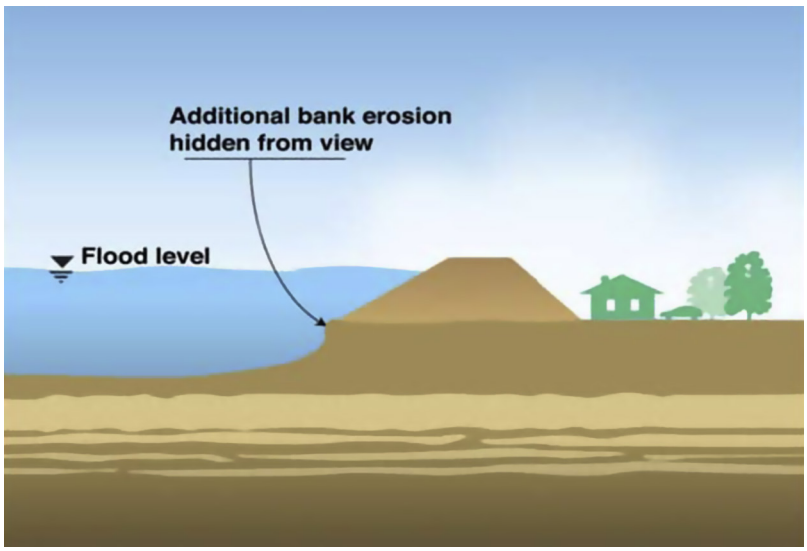

FIGURE 11-2 Hidden levee erosion. *Image courtesy of the California Department of Water Resources, Office of Public Affairs.*

There are several examples of other engineering feats which have achieved success in flood control. The most impressive is the Delta Works, called the Deltawerken in Dutch. Nearly half of the Netherlands is below sea level, and this network of flood protection systems is designed to guard those low-lying areas. The Deltawerken was built after a devastating flood in 1953 where 1836 people died as a direct result of the flooding (Gerritsen, 2005). Thousands of homes were destroyed, and the salt water made the region's farmlands unusable for years. In response, the Delta Works began and has become the largest flood control effort in history. The project's scale is similar to the Great Wall of China. However, even this engineering marvel will need shoring up in several decades as oceans continue rising.

Although dams have excellent social benefits including flood control, power generation, water storage, irrigation, recreation, and more, they have not always been safely maintained. There are approximately 80,000 dams of various sizes, conditions, and vulnerabilities in the United States alone (ACC, 2008). Unfortunately, many of these dams were not built according to any specific standards or have been poorly maintained. They are owned by federal, state, and local government, industry, and private citizens. Managing dams safely becomes more difficult as they age and is particularly challenging with the growing threat of terrorist attacks against critical infrastructure in recent years. The loss of life from a dam failure depends upon how many people live in the dam's floodplain, how severely it can flood if there is a dam collapse, and how much warning is received when a dam failure is imminent (USDOI, 1999).

In a study of over 300 dam failures across multiple continents, the primary reasons for collapse are improper design (40%), flooding exceeding the spillway capacity (35%), and foundation problems such as seepage and settlement (25%) (Biswas and Chatterjee, 1971). Most of the failures are avoidable through proper design and close monitoring. Of course, the exceptions to this include extreme circumstances such as terrorist attacks or unforeseen natural disasters such as earthquakes, which can rapidly compromise a dam's structural integrity.

A significant dam failure occurred in 1975. The Banqiao Dam in China was one of the largest in the world. It was completed in the late 1950s and spanned about one and a quarter miles in length (2 km). The Banqiao Dam held a reservoir the size of Lake Superior in North America. When a large typhoon hit the region, the Banqiao Dam became the first of dozens of dams in the region to fail, killing tens of thousands and displacing millions. Following the failure of the dams, there were subsequent disease outbreaks and famine that killed hundreds of thousands more (USDOI, 1999).

Riverine Flooding

Riverine flooding includes a variety of flood scenarios and types. The nature of a riverine flood is shaped by terrain and weather patterns. One type of riverine flooding is the common overbank flooding seen in many Midwestern US flood disasters (see Fig. 11-3). In

FIGURE 11-3 St. Genevieve, Missouri, July 9, 1993. Cleanup commences at the waterworks following the devastating flood. Federal disasters were declared in 534 counties. *Federal Emergency Management Agency photo by Andrea Booher.*

regions with relatively flat terrain, the water is often shallow and slow moving. It lingers for days or weeks. This is the type of flooding that sandbagging operations are sometimes used to control. It is also the classic scenario most people think of when floods are mentioned.

Flash floods are another type of riverine flood. Narrow, steep valleys quickly collect water in a concentrated area making floodwaters move faster for a shorter duration. Rainfall with sufficient intensity and duration on the right topography can cause flash floods in a very short period. These floods are distinguished by their quick rise and intense, destructive flow. It is not unusual for a flash flood to have a channel velocity of about 9 ft (2.7 m) per second. At that speed, flash floodwaters can move a 90 pound (41 kg) rock downstream. In 1976, Colorado's Big Thompson Canyon experienced a flash flood with a channel velocity of 30 ft per second. At that speed, the floodwater moved 250 ton (227,000 kg) boulders (FEMA, 2006). The density of floodwater makes it exceptionally destructive. Several inches of swift moving water can easily pick up and move vehicles. Moving water can also quickly destroy a home (see Fig. 11-4). Water moving at 10 miles per hour exerts the same pressure on a building as a 270-mile-per-hour blast of wind (Shell, 2005).

Near Glenville, West Virginia, a flash flood hit on a Saturday evening in June 1950. After only 2 in. of local rainfall, local residents did not realize that upstream in Leading Creek, about 8 in. of rain fell shortly after 11 pm, creating a flash flood that would destroy homes across six counties and kill 31 people as the Little Kanawha River crested at over 31 ft (WVA, 1950). The risk from this kind of scenario is significantly reduced today by the National Weather Service Alert System.

FIGURE 11-4 A house going over the top of a local dam in the Texas Flood of 1935—Austin, Texas. *Photo courtesy of the Austin History Center, PICA 008484-A.*

Lake Level Fluctuation Flooding

Lake level fluctuations can result in lake area flooding with a variety of effects. Shoreline erosion can threaten property and homes. Floodwater can intrude into drinking water sources. Septic systems can be compromised and cause private well contamination. The best way to minimize the risk of illness, injury, and property damage due to flooding is to build everything at a higher elevation than the lake's natural outlets. This includes the placement of wellheads and septic systems. Although the outlet may be considerably higher than recorded lake levels, it is the only way to ensure protection from flood risks.

Ground Failure and Flooding

Ground failures include a variety of circumstances including landslides, mudflows, and alluvial fans (Fig. 11-5). The factors contributing to ground failure risks are topography, geology, and precipitation. A hillside comprising certain types of rock and soil can become saturated by precipitation. When moisture lubricates and loosens the soil and rock formations to the point where the slope can give way, a landslide can occur. A landslide sometimes blocks a stream or river and causes flooding upstream from the site. The accumulated debris may also give way and cause a flash flood downstream. Similarly, a mudslide, mudflow, or alluvial fan can focus or redirect debris, rerouting streams and rivers and causing floods. Mudflows can be up to 50% solid material and can cause serious property damage. They can also cause long-term environmental damage as well as compromising drinking water sources. Alluvial fans are fan-shaped deposits of small debris occurring at the foot of a focused drainage area, usually at the base of a mountain range where it opens up to a

FIGURE 11-5 Alluvial fan. During the 1996 Buffalo Creek Fire, thousands of acres southwest of Denver, Colorado, were destroyed. The wildfires lowered the erosion threshold and as a consequence, a 100-year rainstorm in July 1996 caused erosion upstream and deposition of this alluvial fan at the mouth of a tributary to Buffalo Creek. Buffalo Creek is flowing to the right at the bottom of the photograph. *Photo courtesy of the US Geological Survey, by R.H. Meade.*

plain. The unstable soil and excessive moisture lead to debris accumulation from repeated movement of debris by swift moving water. Alluvial fan floods are usually shallow and fast moving. They can carry a substantial amount of sediment and debris, making their flooding difficult to manage.

Coastal Flooding

Coastal flooding occurs when a low-pressure system drives ocean water inland as a storm surge exceeding the normal tidal surge. Tides are produced by the movement of the sun and moon and are very predictable. The natural cycle includes high and low tides, with especially high tides in the spring and autumn. The tide levels also fluctuate with different weather patterns. Low-pressure systems can result from tropical or winter storms and cause storm surges. These storm surges happen several times each year at any given coastal location, but are usually not severe enough to cause serious flooding. However, if a severe storm hits during high tide, flooding can be severe.

Coastal flooding levels are defined as minor, moderate, and major. These are qualitative classifications providing a general description of anticipated flood results:

- Minor: nuisance coastal flooding of locations adjacent to the shore. Minor beach erosion can occur. Minor coastal flooding is not expected to close roads or result in major structural damage to homes and other buildings.

- Moderate: more substantial coastal flooding that threatens life and property. Some roads may become impassable due to flooding. Moderate beach erosion will occur along with damage to some homes, businesses, and other facilities.
- Major: a serious threat to both life and property. Numerous roads will likely become flooded. Many homes and businesses along the coast will receive major damage. People should review safety precautions and prepare to evacuate if necessary. Major beach erosion is also expected (NYCOEM, 2015).

Tsunamis are another type of coastal flooding. Although some tsunamis look similar to a storm surge, they are very different. Potentially massive waves are caused by seismic activity such as earthquakes and volcanoes beneath the ocean. Tsunamis can also be caused by landslides or even a meteorite impact. Swelling to nearly 100 ft high, they travel at hundreds of miles/kilometers per hour. Although some progress has been made in the development of warning systems, there is much work remaining to establish effective systems that can provide sufficient warning for those at risk to evacuate to safety.

Flood Health Threats

The primary causes of flood-related morbidity and mortality are not as apparent or as simple as they may seem. Not all flood-related deaths are attributed to drowning. Other causes of death include physical trauma, fire, electrocution, carbon monoxide poisoning, and heart attacks. Different levels of risk are associated with the type and phases of each flood disaster. A flash flood will have a very different impact on human health from that of a slowly rising and persistent riverine flood. There are also different risks at each phase of the disaster. These may be referred to as risk of direct or indirect injuries or as immediate or delayed injuries. There are also many infectious disease risks associated with the post-flood environment. These risks include those due to contaminated water, spoiled food, and hazardous mold.

Any time a weather disaster occurs in the United States with at least 30 deaths or more than $100 million in damage, the National Weather Service (NWS) investigates and reports on the causes. The most deadly types of floods in the United States are flash floods. A review of NWS flash flood reports from 1969 to 1981 identified 1185 deaths from 32 flash flood events. Detailed information was obtained for 190 of the 1185 fatalities. It was observed that 93% of these deaths were due to drowning. Of those who drowned, 43% were in vehicles (see Fig. 11-6) another 43% were swept into the water when they attempted to cross on foot or were swept into the water from a campsite or home (French et al., 1983). These data suggest that many flood deaths are avoidable.

In an Australian flood fatality review, 2213 flood deaths occurring over a 200-year time span (1788–1996) were analyzed. The review included information from a variety of sources including newspaper articles, government reports, and scientific studies. The majority of fatalities were male. Although the male:female ratio fluctuated over time from

FIGURE 11-6 A car submerged in floodwaters near Moss Bluff, Louisiana, on October 27, 2006. *Photo courtesy of the National Weather Service.*

1:1 to 10:1, the total ratio over the entire period was 4:1. More than 80% of the flood fatalities in Australia have been male. It is interesting to note that more than 38% of these fatalities were due to the risk-taking behavior of attempting to cross a flooded creek, road, or bridge (Coates, 1999). Based on data from this and other flood fatality studies, there are clear opportunities to reduce deaths through enhanced risk communication. Appropriate awareness initiatives may be taken in flood-prone areas to emphasize appropriate messages for those at risk.

Several observations emerged from an analysis of 247 flood-related deaths from 13 different floods across the United States and Europe. The records from these floods were unique, as most included the detailed circumstances of each victim's death. This information provides more insight into lethal hazards than available from many previous flood fatality studies. Nearly 70% of flood deaths were due to drowning, while about 12% were due to traumatic injuries. The balance of the fatalities included an assortment of nondrowning causes, including heart attacks, fires, electrocution, and carbon monoxide poisonings. Here is a summary of the top 10 causes of death among the 247 fatalities (Jonkman and Kelman, 2005):

1. drowning while in a vehicle = 81 (32.8%)
2. drowning as a pedestrian = 62 (25.1%)
3. drowning in a building = 15 (6.1%)
4. physical trauma in a vehicle = 14 (5.7%)
5. heart attack = 14 (5.7%)
6. fire = 9 (3.6%)
7. physical trauma in a building = 8 (3.2%)

8. electrocution = 7 (2.8%)
9. drowning from a boat = 7 (2.8%)
10. physical trauma as a pedestrian = 4 (1.6%)

Morbidity and mortality outcomes vary according to the type of flood and also change with each flood phase. The impact phase is when the majority of injuries and deaths occur. This is especially true with flash floods and dam and levee failures, as well as with other rapid onset floods. However, there are a variety of other risks in slow-rising persistent floods and in the postimpact phase of all floods which contribute to a significant number of injuries and illnesses. During the US Midwest Flood of 1993, surveillance activities included a standardized questionnaire to gather flood-related injury and illness information. From nearly 2 months during the height of the flooding, 524 flood-related conditions were reported and split almost evenly between 250 injuries (47.7%) and 233 illnesses (44.5%) (CDC, 1993).The remaining reports were listed as "other" or "unknown."

Primary injuries included:

- sprains/strains = 86 (34%)
- lacerations = 61 (24%)
- abrasions and contusions = 27 (11%)

Common illnesses included:

- gastrointestinal = 40 (17%)
- rashes/dermatitis = 38 (16%)
- heat illness = 31 (13%)

The risk of postdisaster infectious disease outbreaks is a common concern following a flood. Historically, individuals have died from postdisaster infectious disease conditions including malaria, respiratory infections, and diarrhea (Lignon, 2006). Locations with endemic disease or inadequate public health infrastructure are far more likely to see postdisaster outbreaks. In developed nations, it is rare to observe increases in serious infectious conditions following a disaster (Shultz et al., 2005).

Based on disaster research, the nondrowning hazards following a flood include the risk of fire, electrocution, and carbon monoxide poisoning. Injuries include sprains, strains, lacerations, bruises, and other injuries, while illnesses include gastrointestinal illness, rashes, respiratory conditions, and other illnesses (Doocy et al., 2013; EM-DAT: OFDA/CRED, 2004). These hazards, injuries, and illnesses can be avoided by following recommendations offered by the Centers for Disease Control and Prevention. These recommendations include avoiding electrical hazards, hazardous materials, carbon monoxide, and dangerous wild or stray animals. The CDC also provides instructions for sanitation and precautions to take to ensure safe food and drinking water following a flood. However, the most problematic postflood hazard is mold.

FIGURE 11-7 Excessive mold growth on the ceiling of a water-damaged residence. *Photo courtesy of the Centers for Disease Control and Prevention.*

There are thousands of varieties of mold ubiquitous in the environment which can survive under harsh conditions for long periods of time. As a part of the natural environment, the majority of these molds are harmless to people. The problem arises when a flood provides an ideal environment for molds to quickly grow inside buildings. Depending on the type of mold, it can cause severe problems for those cleaning up after a flood or for those who reoccupy flooded buildings (see Fig. 11-7). Some people are sensitive to molds and experience allergic reactions, whereas others with preexisting respiratory and immunocompromised conditions are at risk for more severe consequences. Those who are sensitive typically have allergic reactions including nasal congestion, wheezing, and eye or skin irritation. Illness can be severe in those with overwhelming exposures or with preexisting conditions. For example, those with chronic obstructive pulmonary disease are at risk for mold infections of the lungs. There has been a particular emphasis on "toxic molds." This is an inaccurate definition, as even the molds most prone to producing mycotoxins do not always produce them, and there are so many different molds capable of producing the same toxin, it is an inaccurate way to define the problem (IOM, 2004). Regardless of the suspected type of mold, those with respiratory conditions should avoid exposure. Following a significant flooding episode, the US Environmental Protection Agency recommends even for those who are healthy, if the visible mold growth exceeds 10 square ft (1 square meter), a professional remediation service should be considered (EPA, 2010).

Racism and the Far-Reaching Impact of Floods

In 1927, an unusually large amount of rainfall began threatening the new levee system in place along the Mississippi River. Levees broke in 145 places from Missouri to Louisiana, unleashing the worst disaster in US history up to that point in time. Over 26,000 square miles (67,000 square km) of land were flooded, disrupting the lives of nearly a million residents. More than 200 people died, thousands of buildings were destroyed, and crops and farm animals were lost (ANRC, 1929). Relief shelters, referred to as "concentration camps," were established to house more than 300,000 displaced persons. Nearly 70% of those displaced were African Americans. With a shortage of laborers to work on the relief efforts and levees, the local authorities of Greenville, Mississippi began recruiting African American laborers at gunpoint. The African American population comprised 75% of the area population and 95% of the labor for the regional farms and plantations. At one point, with little shelter or supplies, 13,000 African American workers were left on a levee cut off by flooding. Under the direction of Will Percy, the head of the Flood Relief Committee, boats arrived to evacuate the trapped residents to safety but only evacuated white survivors. Will Percy later requested that the American Red Cross make the town a regional distribution center for relief supplies. As supplies were distributed, only white residents and African American workers with "Laborer" tags showing they were "volunteer" laborers were allowed access to rations. The black residents without tags were excluded from distribution (PBS, 2013).

The sociopolitical influence this disaster had on the United States was enormous. After the disaster, the 1928 Flood Control Act was passed and initiated the building of today's modern levee system on the Mississippi (Pearcy, 2002). The injustices of this flood response were a major factor in the migration of large numbers of African Americans to Northern cities. For those staying in the region, the stories of racially motivated abuse and neglect during this flood contributed to shaping the musical style known as the Blues. Charlie Patton recorded "High Water Everywhere" and Lonnie Johnson released the "Broken Levee Blues." These events also influenced the political tide and began moving African American support from the Republican to the Democratic Party (Watkins, 1997). Many changes set in motion by the 1927 Mississippi flood continue to influence public health and emergency management in the United States today.

Prevention

Preparing for floods requires the same basic preparation as for any other disaster scenario. A family preparedness plan should be developed. This includes a minimum of several days of supplies and a communication plan including out of town contacts to be notified by separated family members. The risk for flooding should be understood (see Fig. 11-8). This flood risk information can be acquired with the assistance of local government planning offices. There is a searchable flood map on the Federal Emergency Management Agency website for US residents. Several other nations have similar online tools available.

FIGURE 11-8 Midwest Great Flood of 1993—extensive flooding outside the Missouri capital of Jefferson City. *Photo courtesy of the US Geological Survey.*

Building in flood-prone areas should incorporate elevated and reinforced designs. The water heater, furnace, electrical panel, fuel storage, and other essential equipment should be elevated as much as possible above the potential flood level. Check valves should be included in sewer traps to prevent floodwater backups. Basement areas should be sealed to minimize floodwater intrusion.

Ten Individual Flood Preparedness Messages

1. Identify the types of flood risks where you live, work, go to school, or travel.
2. Avoid building in floodplains, but if you do, include design features which elevate the HVAC and other essential equipment.
3. Store essential supplies in a home disaster kit.
4. Establish a communication plan with your family.
5. Identify a safe evacuation location outside the potential flood zone.
6. Identify vulnerable friends and neighbors who may need assistance.
7. Keep a smaller preparedness kit in your vehicle.
8. Plan transportation options if bridges or roads become impassable.
9. Learn how to use a fire extinguisher and maintain at least one in your home.
10. Get trained in first aid and be prepared to help others during a crisis.

Immediate Actions

The initial actions taken during a flood should be based upon direct observations (made without adding personal risk) and on public announcements and warnings of local officials. Any time a flood is possible due to weather or other factors, announcements should be made on local radio and television with specific hazard and evacuation information. Officials can also communicate important information to the public using the emergency alert system. If water is slowly rising and there is time to prepare, the home should be secured by bringing in outdoor furniture and other items which can be carried away or made into loose debris by floodwaters. Important items and valuables should be moved to the highest level of the structure. Utilities should be turned off using the main switches and valves, and electrical appliances should be unplugged. Public messages should emphasize that major causes of morbidity and mortality during and following a flood are electrocution, fires, and other nondrowning causes. If the risk for flash flooding is high, individuals should not wait for local officials to issue evacuation orders. In imminent flash flood circumstances, additional time should not be taken to shut down utilities or move furniture or other items to higher levels of a structure. Immediate evacuation to a safe location is necessary. Those evacuating should be aware of the following:

- Be aware of streams, channels, canyons, and other areas known to flood suddenly. Flash floods can occur in these areas with or without official warnings or signs such as rain clouds or heavy rain.
- Do not walk or drive through moving water. As little as 6 in. of moving water can cause you to fall. If you must wade through water, use a stick to check for the depth of the water and the firmness of the ground in front of you.
- The leading cause of death in floods is drowning in a vehicle. Do not drive in flooded areas. You and your vehicle can be swept away. If floodwaters rise around your car, abandon it and move to higher ground.
  - Water rising to a height of 6 in. is enough to reach the bottom of most passenger cars. It can cause loss of control or possible stalling of the vehicle.
  - A foot of water will float most vehicles.
  - Two feet of rushing water can carry away most vehicles, including SUVs and pickups.

An event occurred as a result of a slow-moving thunderstorm along a canyon near Big Cove, North Carolina, in September 1990. Although the thunderstorm produced only a quarter of an inch of rainfall in the town of Cherokee, rainfall estimates upstream exceeded 6 in. in less than 2 hours. The heavy rainfall produced a wall of water rushing down a small stream. Water levels rose to 25 ft in minutes in some areas. Because of the flash flood watch issued by the National Weather Service, the Emergency Manager for the Eastern Band of the Cherokee Reservation reacted immediately, and the 911 dispatcher sent fire/rescue units to begin an evacuation. As a

result of the flash flood watch, subsequent flash flood warnings, and quick actions by the local authorities, no lives were lost. It is reasonable to assume in similar flash flood events occurring at night in canyons, over 20 people would have drowned. In addition, much property damage was averted (NHWC, 2002).

Response and Recovery Challenges

Once a flood is over, the immediate actions taken will be dictated by local officials and by the observed environmental impact. Buildings can be damaged and structurally weakened by floodwaters. Landslides or mudslides may also occur. People and livestock may die due to drowning, and in large quantities, decaying bodies may pose public health risks (see Fig. 11-9).

FIGURE 11-9 Wallace, North Carolina, September 28, 1999—nearly 750,000 turkeys were lost to flooding in Duplin County alone, as well as 100,000 hogs, including over 23,000 on this poultry farm in Wallace. The owner, Alan Reynor, lost at least $85,000 plus cleanup costs. He also lost 2500 hogs and his corn crop. *Photo by Dave Gatley courtesy of the Federal Emergency Management Agency.*

Secondary effects of floods include the contamination of drinking water and general poor environmental health conditions in flooded buildings. Dead animals, leaked fuel, sewage, and other contaminants may be displaced into wells and other important water sources. Debris must be removed and the water "shocked" with chlorine to restore potable, healthy conditions. Floods can also cause food shortages due to direct crop damage or loss of livestock. Spoilage of personal or commercial food supplies can also occur if there are significant prolonged power outages.

Long-term effects of flooding include economic adversity from cleanup and rebuilding costs, food shortages, and declines in tourism and other key businesses. These impacts are often carried more by the poor in the affected communities. There will also be long-term psychological issues among those who have lost loved ones or experienced serious personal or economic losses from the disaster.

FIGURE 11-10 New Orleans, Louisiana, September 1, 2005—evacuees and hospital patients arrive at New Orleans airport where FEMA's Disaster Medical Assistance Teams have set up operations. New Orleans is being evacuated as a result of flooding caused by Hurricane Katrina. *Photo: Michael Rieger/FEMA.*

After a flood evacuation, public messages should be used to instruct the community whether or not to return and when and how to return safely, and to provide information on sheltering, reunification of families, and disaster relief services (see Fig. 11-10). Once floodwaters recede, some roads may have weakened to the point that they may collapse under the weight of a vehicle, and these weaknesses are not always apparent to those driving on weakened roads. If instructed that it is safe to return, other hazards such as downed power lines or residual floodwaters may be discovered. Standing floodwater and mud may be

contaminated with sewage, petroleum products, or other hazardous substances. Because of possible contamination, anything which has been wet or in contact with the floodwaters must be disposed of or cleaned. Power and water systems will need to be checked before reinstituting utilities.

As the affected population begins to reenter the area, it is important to establish a visible support system across the community. Everyone must take care of themselves as well as look out for each other throughout these types of chronic disaster recovery periods. Floods can take months or even years for full recovery, and those most affected must be reminded to take care of themselves. This includes fundamental reminders to eat and rest, keep a manageable schedule, and discuss concerns with friends, family, or professional counselors. Basic postflood safety reminders are also important. This includes the reminders below.

Protection Against Foodborne or Waterborne Disease Threats

- Consider all water unsafe until local authorities announce the public water supply is safe.
- Test private wells to ensure the water is potable if there is a possibility of floodwater intrusion.
- Do not use contaminated water to drink, wash or prepare food, brush teeth, wash dishes, or make ice.
- Keep an adequate supply of safe water available for bathing and potable water for drinking.
- If the safety of a food or beverage is questionable, throw it out.
- Do not allow children to play in floodwater areas.
- Do not allow children to play with toys contaminated by floodwater. Use a 1:10 bleach:water solution to disinfect impermeable toys.

Protection Against Physical Threats

- Avoid slips, trip, and falls. Wear sturdy shoes.
- Be aware of potential electrical hazards.
- Have the structure's electrical system checked by a professional before turning on the power.

Protection Against Chemical Threats

- Be alert for chemically contaminated floodwater at industrial or agricultural sites.
- Use extreme caution with potential chemical and electric hazards which have great potential for fires and explosions. Any chemical hazards, such as a propane tank, should be handled by the fire department or police.
- Be aware of carbon monoxide hazards. Do not use generators or burn charcoal indoors.
- Wear PVC or nitrile (not disposable or latex) gloves, rubber boots, and goggles or safety glasses during floodwater cleanup.

Protection Against Mold

- If you or your family members have health problems after exposure to mold, contact your doctor or other healthcare provider.
- Controlling moisture in your home is the most critical factor for preventing mold growth.
- Clean and dry those materials that can be completely dried.
- Remove damaged materials that cannot be completely dried, including any materials that cannot be thoroughly cleaned and dried within 24–48 hours.

Protection Against Wound Infections

- Avoid exposing open wounds to floodwater.
- Keep open wounds as clean as possible by washing with soap and clean water.
- Seek immediate medical care if a wound develops redness, swelling, or other signs of infection.

Protection Against Animal Threats

- Floodwaters can displace animals, insects, and reptiles. Seek immediate medical care for all animal bites.
- Beware of snakes.

Protection Against Mosquitoes

- Use insect repellant containing at least 10% DEET.
- Dress in long sleeves and long pants.
- Drain standing water around your home.

Summary

Floods are the most common natural disasters. They affect millions of people globally each year and are responsible for many deaths and economic losses. Although it is no surprise that the majority of these deaths are from drowning, other causes of death from flooding are less apparent, including electrocution, fires, traumatic injury, and carbon monoxide poisoning. There are also many preventable deaths associated with flooding disasters. Because the majority of fatalities result from risk-taking people crossing flooded areas on foot or in vehicles, basic risk communication efforts in flood-prone areas may have the potential to reduce fatalities. Other nonfatal injuries and illnesses can be reduced through regular reminders for those in flooded areas about the range of risks they may encounter during and after the flood and how these risks can be reduced.

A variety of flood types pose different challenges at various stages of the disaster. Flash floods are often unpredictable, but effective planning and warning systems can reduce community risks. There are unique hazards associated with flood walls, levees, and dams.

Though many of these systems provide protection from slow-rising riverine floods, they may also increase the likelihood of rapid, violent flooding resulting from structural failure.

The greatest public health challenges following flooding are associated with the environmental health impact of flooded infrastructure. Disrupted utilities can pose risks including explosions. Fires from gas leaks can occur as well as electrocutions from downed or submerged power lines. Infectious diseases may increase following a flood, and water or food supplies may be contaminated from floodwaters or chemical exposures. The general sanitation of flooded buildings poses ongoing postflood risks, and the rapid growth of dangerous molds is a problem often requiring professional remediation. Ensuring a safe environment during recovery is extremely difficult and requires preplanning.

Flooding disasters will continue to grow in frequency as urbanization continues near waterways and coastal areas. Healthcare and public health preparedness measures associated with floods must be specifically tailored for each region according to the types of potential floods which may occur and the populations which may be impacted. At the heart of an effective flood response and recovery plan is a thorough assessment of flood risks across each region and a tailored public education effort before, during, and after a flood.

Websites

American Red Cross, Flood Safety. http://www.redcross.org/prepare/disaster/flood.

British Columbia, Provincial Emergency Program, Personal Flood Preparedness and Prevention (In English, Punjabi, and Chinese). www.pep.bc.ca/floods/preparedness.html.

Centers for Disease Control and Prevention, Flood Preparedness. www.bt.cdc.gov/disasters/floods/.

City of New Orleans, Dealing with Storm Water. http://www.nola.gov/hazard-mitigation/stormwater/.

Federal Emergency Management Agency, Flood Preparedness. http://www.ready.gov/floods.

Floodsmartgov, The Official Site of the National Flood Insurance Program. https://www.floodsmart.gov/floodsmart/.

Harris County Public Health and Environmental Services, Texas, Flood Preparedness. http://www.hcphes.org/publications/hcphes_responds/severe_weather/floods/.

International Centre for Water Hazard and Risk Management. http://www.icharm.pwri.go.jp/.

International Flood Initiative. http://www.ifi-home.info/.

International Flood Network. http://www.internationalfloodnetwork.org/.

National Weather Service, Flood Safety. http://www.floodsafety.noaa.gov/.

National Weather Service, TsunamiReady. http://www.tsunamiready.noaa.gov/.

North Dakota State University, Flood Recovery Information. https://www.ag.ndsu.edu/flood/.

U.S. Geological Survey, Flood Information. https://water.usgs.gov/floods/resources/.

World Meteorological Organization, Hydrology and Water Resources. http://www.wmo.int/pages/prog/hwrp/index_en.php.

World Health Organization, Flooding and Communicable Diseases Fact Sheet. http://www.who.int/hac/techguidance/ems/flood_cds/en/.

World Health Organization, Drowning Fact Sheet. http://www.who.int/mediacentre/factsheets/fs347/en/.

References

American City & County (ACC), September 3, 2008. Report Says U.S. Dams Require Better Security. Government Security. Available at: http://americancityandcounty.com/security/homeland/us-dam-security-0904.

American National Red Cross (ANRC), 1929. The Mississippi Valley Flood Disaster of 1927: Official Report of Relief Operations of the American National Red Cross. American National Red Cross, Washington, DC.

Biswas, A.K., Chatterjee, S., 1971. Dam disasters—an assessment. Eng. J. Montr. 54 (3) EIC-71-HYDEL3.

Centers for Disease Control and Prevention (CDC), 1989. International notes health assessment of the population affected by flood conditions—Khartoum, Sudan. MMWR 37 (51–52), 785–788. Available at: www.cdc.gov/mmwr/preview/mmwrhtml/00001323.htm.

Centers for Disease Control and Prevention (CDC), 1993. Morbidity surveillance following the midwest flood—Missouri, 1993. MMWR 42 (41), 797–798. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/00022056.htm.

Coates, L., 1999. Flood fatalities in Australia, 1788–1996. Aust. Geogr. 30 (3), 391–408.

Centre for Research on the Epidemiology of Disasters (CRED), 2004. EM-DAT: The International Disaster Database. Available at: http://www.emdat.be/database.

Davies, H.R.J., Walsh, R.P.D., 1997. Historical changes in the flood hazard at Khartoum, Sudan: lessons and warnings for the future. Singap. J. Trop. Geogr. 18, 123–140.

Department of State (DOS), 2015. U.S. Embassy, About Sudan: The Three Towns. Khartoum, North Khartoum and Omdurman. Available at: http://sudan.usembassy.gov/3_towns.html.

Doocy, S., Daniels, A., Murray, S., Kirsch, T.D., April 16, 2013. The human impact of floods: a historical review of events 1980–2009 and Systematic Literature review. PLOS Curr. Disasters. Edition 1 http://dx.doi.org/10.1371/currents.dis.f4deb457904936b07c09daa98ee8171a.

El Nasser, H., September 18, 2005. A New Orleans Like the Old One Just Won't Do. USA Today. Available at: www.usatoday.com/news/nation/2005-09-18-new-orleans-rebuilding_x.htm.

EM-DAT: OFDA/CRED, 2004. International Disaster Database. Université Catholique de Louvain, Brussels, Belgium. http://www.emdat.be/.

Environmental Protection Agency (EPA), 2010. A Brief Guide to Mold, Moisture, and Your Home. EPA Publication 402-K-02-003. Available at: www.epa.gov/iaq/molds/images/moldguide.pdf.

Federal Emergency Management Agency (FEMA), 2006. Floodplain Management Course, Session 6.

French, J., Ing, R., Von Allmen, S., Wood, R., 1983. Mortality from flash floods: a review of National Weather Service Reports, 1969–81. Public Health Rep. 98 (6), 584–588.

Gerritsen, H., 2005. What happened in 1953? The big flood in the Netherlands in retrospect. Philos. Trans. R. Soc. A 363, 1271–1291.

Hunter, M., May 19, 2006. Deaths of Evacuees Push Toll to 1,577: Out-of-state Victims Mostly Elderly, Infirm. The Times-Picayune.

Institute of Medicine (IOM) Committee on Damp Indoor Spaces and Health, 2004. Damp Indoor Spaces and Health. The National Academies Press, Washington, DC.

Jonkman, S.N., Kelman, I., 2005. An analysis of the causes and circumstances of flood disaster deaths. Disasters 29 (1), 75–97.

Lignon, B.L., 2006. Infectious diseases that pose specific challenges after natural disasters: a review. Semin. Pediatr. Infect. Dis. 17, 36–45.

State of Louisiana (LA), September 12, 2006. Health Department Releases Family Assistance Center Final Report. Available at: http://dhh.louisiana.gov/index.cfm/newsroom/detail/646.

National Hydrologic Warning Council (NHWC), May 2002. Use and Benefits of the National Weather Service River and Flood Forecasts. Available at: http://nws.noaa.gov/oh/ahps/AHPS%20Benefits.pdf.

New York City Office of Emergency Management (NYCOEM), 2015. New York City Hazards: Coastal Flooding. Available at: http://www.nyc.gov/html/oem/html/hazards/storms_coastalflooding.shtml.

Pearcy, M.T., 2002. After the flood: a history of the 1928 Flood Control Act. J. Ill State Hist. Soc. Available at: http://www.jstor.org/stable/40193521?seq=1#page_scan_tab_contents.

Public Broadcasting Service (PBS), 2013. American Experience: Fatal Flood Timeline. Available at: http://www.pbs.org/wgbh/americanexperience/features/timeline/flood/.

Shell, A., 2005. Floods Can Cause Damage to Structure. USA Today. September 9, 2005:3B. Available at: www.usatoday.com/money/perfi/housing/2005-09-08-wet-homes-usat_x.htm.

Shultz, J.M., Russell, J., Espinel, Z., 2005. Epidemiology of tropical cyclones: the dynamics of disaster, disease, and development. Epidemiol. Rev. 27, 21–35.

U.S. Department of Interior (USDOI), 1999. A Procedure for Estimating the Loss of Life Caused by Dam Failure. Bureau of Reclamation Report DSO-99-06. Available at: http://www.usbr.gov/ssle/damsafety/documents/RCEM-Methodology.pdf.

Walsh, R.P.D., Davies, H.R.J., Musa, S.B., 1994. Flood frequency and impacts at Khartoum since the early nineteenth century. Geogr. J. 160 (3), 266–280.

Watkins, T.H., April 13, 1997. Boiling Over: The 1927 Mississippi Flood Was a Caldron of Racism and Greed. New York Times. Available at: www.nytimes.com/books/97/04/13/reviews/970413.13watkint.html.

West Virginia Archives and History (WVA), June 30, 1950. Worst Flash Flood in History Sweeps Troy and Other Communities: Thirty-one Known Dead in 6-county Area; Little Kanawha River Hits Crest of 31.1 at Glenville. Glenville Pathfinder. http://www.wvculture.org/history/disasters/flood195001.html.

12

Foodborne Threats

OBJECTIVES

- Describe the limitations of available foodborne disease data.
- Summarize the international measures put in place to reduce foodborne risks.
- List the most common pathogens causing foodborne outbreaks.
- Explain who is at greatest risk of foodborne disease and why.
- Describe nonbiological foodborne threats.
- Explain how food can be used in an act of bioterrorism.
- Describe how food can be contaminated in the natural environment or through industrial farming operations.
- List basic food handling safety measures.
- Describe the multidisciplinary team needed to investigate a foodborne outbreak.
- Explain the two most important characteristics of a foodborne outbreak investigation.

Introduction: 2011 US Listeriosis Outbreak

Charles "Chuck" Palmer and his wife Tammie were retired. After a long career in the United States Marine Corps, including service in the Vietnam War, Chuck retired as a master sergeant. He and Tammie had been living in Colorado Springs, Colorado, for about 8 years. He enjoyed his cockatiels and trained them to repeat the Marine Corps motto, "Semper Fi," which means "always faithful." Chuck also loved fruit and sometimes had nothing but fruit for lunch. His favorites were melon, grapes, and apples. Several days after eating cantaloupe, he began having a severe headache. By the next day, he became weak and nauseated. After a bout of dry heaves, Tammie tried speaking with him but he would not respond. In frustration she slapped his face, asking him to respond, but he could not. An EMS crew arrived at their home after she called 911, and Chuck was taken to the hospital. A month later he had regained his speech but remained weak and confused (Elliot, 2011). He never fully recovered from an infection of *Listeria* bacteria traced back to a cantaloupe he had eaten (Vanderveen, 2013).

Chuck Palmer was one of 147 individuals across 28 states who experienced listeriosis as a result of eating cantaloupes contaminated with *Listeria monocytogenes*. There were 33 outbreak-associated deaths reported to the Centers for Disease Control and Prevention (CDC, 2012). The contaminated cantaloupes were traced back to a farm in Colorado. The FDA investigators concluded there were two ways it could have been introduced into the processing plant. There may have been *L. monocytogenes* in the field where the cantaloupes were grown, with the result that the processing of the contaminated cantaloupes

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A young boy's day out to the lake, pictured here holding a slice of cantaloupe. *Photo by Amanda Mills courtesy of the Centers for Disease Control and Prevention.*

could have introduced the organism into the processing plant. The other possible means of introduction was a truck parked next to the facility. The truck was used to transport culled cantaloupe to a cattle farm. The *L. monocytogenes* was likely allowed to spread in the processing facility due to the design of the facility and equipment. Both the facility and the processing equipment were difficult to clean. The growth of the organisms was also promoted in part by the handling of the cantaloupes between the field and cold storage. There was a precooling step missing from the process. Without this step, the cantaloupes may have developed condensation while cooling. This could have further promoted *L. monocytogenes* growth (USFDA, 2012; ElBoghdady, 2011). This was the fourth deadliest foodborne outbreak in US history and the worst in over 85 years (Flynn, 2012).

Foodborne Illness Definitions

Confirmed disease outbreak A foodborne disease outbreak with laboratory confirmation of appropriate specimens identifying a causative agent with epidemiological analysis implicating a food as the source of the illness.

Critical control point A process or procedure in a specific food system where loss of control or compliance may result in potentially hazardous food.

Critical limit The maximum or minimum value to which a physical, biological, or chemical parameter must be controlled at a critical control point to minimize the risk of a food safety hazard.

***E. coli* (*Escherichia coli*)** A bacteria normally found in the intestines of animals and humans. There are hundreds of different strains. The most harmful, *E. coli* O157:H7, produces a powerful toxin and can cause severe illness and death.

Enterohemorrhagic *Escherichia coli* (EHEC) *E. coli* bacteria which cause hemorrhagic colitis, meaning bleeding enterically or bleeding from the intestine. Usually associated with *E. coli* capable of producing Shiga toxins, and is a subset of Shiga toxin–producing *Escherichia coli* (STEC). EHEC infections can be asymptomatic but are typically associated with bloody diarrhea (hemorrhagic colitis) and hemolytic uremic syndrome (HUS) or thrombotic thrombocytopenic purpura (TTP).

Foodborne disease outbreak The occurrence of two or more cases of a similar illness resulting from the ingestion of a common food.

Food safety Practices and conditions which preserve the quality of food by preventing contamination and foodborne illnesses.

Hemolytic uremic syndrome (HUS) A condition resulting from abnormal premature destruction of red blood cells. Damaged red blood cells clog the filtering system in the kidneys, which can lead to life-threatening kidney failure.

Hemorrhagic colitis An acute condition caused by *E. coli* O157:H7. The illness is characterized by severe cramping (abdominal pain) and diarrhea which starts out watery but becomes exceptionally bloody.

Highly susceptible population Individuals at increased risk of foodborne disease because they are immunocompromised, preschool age children, or older adults.

Major food allergen Foods with milk, egg, fish, crustacean shellfish, tree nuts (almonds, pecans, or walnuts), wheat, peanuts, and soybeans.

Potentially hazardous foods Foods which require time/temperature control for safety to avoid rapid growth of infectious and toxin-producing microorganisms. Usually foods high in protein and moisture content with low acidity. These foods include, but are not limited to meat products, seafood products, dairy products, cooked foods, and some fresh cut produce (melons, tomatoes, etc.).

Sanitation Application of cumulative heat or chemicals on cleaned food-contact surfaces sufficient to yield a reduction of five logs, equal to a 99.999% reduction of microorganisms of public health concern.

Shiga toxin-producing *Escherichia coli* (STEC) *E. coli* bacteria capable of producing Shiga toxins (also called verocytotoxins or "Shiga-like" toxins). Examples of serotypes of STEC include both O157 and non-O157 *E. coli*.

Thrombotic thrombocytopenic purpura (TTP) A disorder causing blood clots to form in small blood vessels leading to a low platelet count (thrombocytopenia). The small blood clots, called thrombi, can prevent oxygen from reaching these parts of the body and damage organs including the kidneys, heart and brain.

Primary Foodborne Disease Threats

Foodborne disease outbreaks are among the most common public health threats in the world. They are also the most underreported and least understood. Global estimates for foodborne infectious diseases are lacking. Since a large proportion of diarrheal disease involves foodborne sources, the incidence of acute gastroenteritis provides some insights into the scale the problem. Children in developing countries are among the most vulnerable to increased morbidity and mortality due to diarrheal disease. Nearly one in five deaths of children in developing nations in their first five years of life are attributed to diarrheal disease (Kosek et al., 2003). Although efforts to reduce diarrheal disease prevalence continue to improve, there are still

Table 12-1 Top 10 Deadliest Foodborne Outbreaks in US History

	Year	Location/Origin	Source	Illness	Deaths
1	1924–25	New York, Chicago, and Washington, D.C.	Oysters from long Island, NY	Typhoid	150
2	1903	Ithaca, NY	Public water source	Typhoid	82
3	1911	Boston, MA	Raw milk	*Streptococcus*	48
4	2011	28 States, Origin: Colorado	"Rocky Ford" cantaloupes	*Listeria*	36
5	1985	Los Angeles, CA	Mexican cheese	*Listeria*	28
6	1922	Portland, OR	Raw milk	*Streptococcus*	22
7	1998	Origin: Michigan	Ball Park hot dogs and Sara Lee deli meats	*Listeria*	21
8	1919	Origin: California	Canned ripe olives	Botulism	19
9	2008–09	46 states, Origin: King Nut, Blakely, Georgia	Peanut butter and paste	*Salmonella typhimurium*	9
10	2002	New York, Maryland, Pennsylvania, New Jersey	Pilgrim's Pride turkey meats	*Listeria*	8

Adapted from Flynn (2012).

millions of adults and children globally who die from diarrheal disease resulting from contaminated food and water. Most foodborne and waterborne disease outbreaks are managed using existing public health infrastructure, with some external support provided by the international community for nations with minimal resources. However, there are occasions when foodborne disease threats or outbreaks become a regional, national, or international public health emergency or disaster (see Table 12-1).

The globalization of the food markets has improved the availability and variety of food sources globally, and improved the health of both the people and the economies of many developed and developing nations. A variety of initiatives are in place to ensure that this global expansion occurs in a manner which maintains food safety, protecting against pests and pathogens. The World Trade Organization developed standards for sanitary (animal health) and phytosanitary (plant health) safety, referred to as "SPS Measures." According to the European Commission, these measures include all "relevant laws, decrees, regulations, requirements and procedures" to protect human, animal and plant health in the import and export of food products. This includes addressing risks from "plant pests (insects, bacteria, and viruses), additives, residues (of pesticides or veterinary drugs), contaminants (heavy metals), toxins or disease-causing organisms in foods, beverages or feedstuffs, and diseases carried by animals" (EC, 2013). All SPS measures are based on science-based risk assessments.

Estimating or measuring foodborne disease burdens of nations around the world is very difficult. The linkages of illnesses to food are usually only examined and measured when there are serious outbreaks. The use of diarrheal disease as a data surrogate for foodborne illness is complicated, as relatively few cases are reported, not all diarrheal disease is caused by foodborne pathogens, and not all foodborne pathogens cause gastrointestinal problems.

The pathogenic organisms associated with foodborne outbreaks vary significantly from one geographic region to another. There are eight pathogens in the United States which

Table 12-2 Top Organisms Contributing to US Foodborne Illnesses, Hospitalizations, and Deaths

Organism	Illnesses (%)	Hospitalizations (%)	Deaths (%)
Norovirus	58	26	11
Salmonella, nontyphoidal	11	35	28
Clostridium perfringens	10	<4	<6
Campylobacter spp.	9	15	6
Staphylococcus aureus	3	<4	<6
Toxoplasma gondii	<3	8	24
E. coli (STEC) O157	<3	4	<6
Listeria monocytogenes	<3	<4	19

Adapted from CDC (2014).

account for almost all foodborne illnesses, hospitalizations, and deaths (see Table 12-2). Norovirus accounts for over half (58%) of all foodborne illnesses (Fig. 12-1). It is also the second-leading cause of hospitalizations (26%) and fourth-leading cause of death (11%). *Salmonella*, nontyphoidal, accounts for 11% of all illnesses, but is the leading cause of foodborne illness hospitalization (35%) and death (28%) (Fig. 12-2) (Scallan et al., 2011; CDC, 2014).

In 2010, Australia experienced about 30,840 hospitalizations and approximately 76 deaths related to foodborne pathogens, parasites, and related diseases. Four causative agents accounted for 93% of foodborne illnesses: Norovirus, *Escherichia coli*, *Campylobacter* spp., and *Salmonella* nontyphoidal (Kirk et al., 2014). When compared to the most prevalent

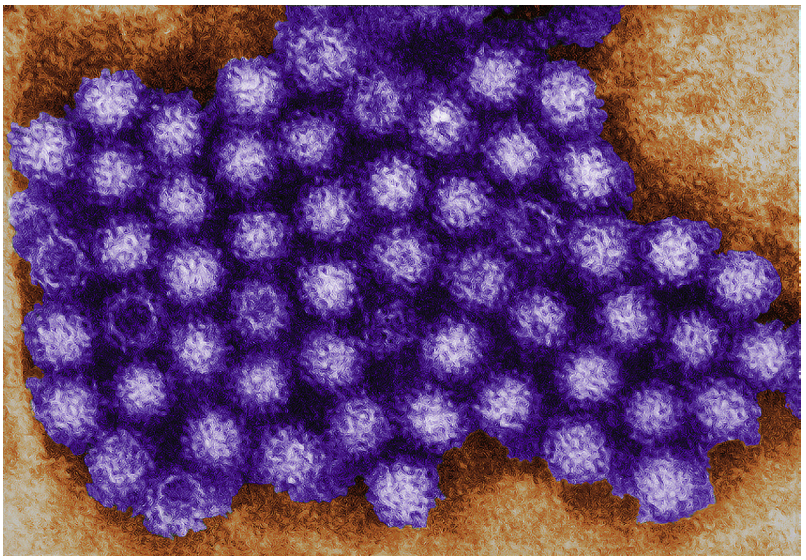

FIGURE 12-1 Transmission electron micrograph image of norovirus virions, or virus particles. *Photo by Charles D. Humphrey courtesy of the Centers for Disease Control and Prevention.*

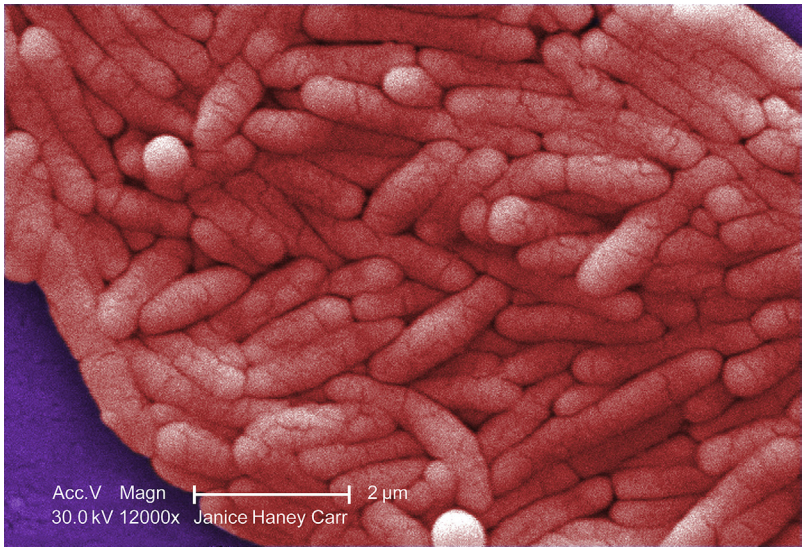

FIGURE 12-2 Scanning electron micrograph image of large grouping of Gram-negative *Salmonella typhimurium* bacteria that had been isolated from a pure culture. *Photo by Bette Jensen courtesy of the Centers for Disease Control and Prevention.*

foodborne illnesses in the U.S., Australia has the same leading cause, Norovirus, but has a second-leading cause, *E. coli*, which is not in the top five leading causative agents in the United States. In England, rotavirus is the third-leading cause of foodborne illness, following Norovirus and *Campylobacter* spp. (Adak et al., 2002). Like all infectious diseases, the causative agents of foodborne illnesses, hospitalizations, and deaths vary between nations.

Human Health Effects

Foodborne illnesses can result from a wide range of food and water contaminants. There are two general categories of foodborne illnesses: foodborne infection and foodborne intoxication. Both types of illness result from ingestion of pathogens into the digestive tract. Foodborne infections are more likely and more severe among populations with compromised immune systems. Infections involve pathogenic invasion of body tissue or organs. Invasive infections include bacteria, viruses, and parasites. Some of the more common infections include *Campylobacter*, *Salmonella*, and *Shigella*. Other bacteria are considered noninvasive, yet still capable of colonizing or multiplying in the gastrointestinal tract and producing dangerous toxins. These include *Bacillus cereus* and *Clostridium botulinum*. Foodborne intoxications are caused by ingestion of the toxins in food products that come from many of the same organisms as the noninvasive bacteria already mentioned. When the food product has been colonized and there is a sufficient accumulation of toxins prior to ingestion, rapid onset of illness from the direct ingestion of toxins can occur. This rapid onset of symptoms differs from the delayed onset of symptoms when bacteria is ingested, colonizes the gastrointestinal tract, and then releases toxins. Table 12-3 summarizes many common sources of foodborne illness including bacteria, bacterial toxins, viruses, parasites, and allergens.

Table 12-3 Bacteria, Bacterial Toxin, Virus, Parasite, and Allergen Sources and Presentation of Illnesses

Agent	Incubation Period	Symptoms	Symptom Duration	Common Sources
Bacillus anthracis	2 days to weeks	Nausea, vomiting, malaise, bloody diarrhea, acute abdominal pain	Weeks	Insufficiently cooked contaminated meat
Bacillus cereus (diarrheal toxin)	10–16 hours	Abdominal cramps, watery diarrhea, nausea	24–48 hours	Meats, stews, gravies, vanilla sauce
B. cereus (preformed enterotoxin)	1–6 hours	Sudden onset of severe nausea and vomiting. Diarrhea may be present	24 hours	Improperly refrigerated cooked or fried rice, meats
Brucella abortus, B. melitensis, and *B. suis*	7–21 days	Fever, chills, sweating, weakness, headache, muscle and joint pain, diarrhea, bloody stools during acute phase	Weeks	Raw milk, goat cheese made from unpasteurized milk, contaminated meats
Campylobacter jejuni	2–5 days	Diarrhea, cramps, fever, and vomiting; diarrhea may be bloody	2–10 days	Raw and undercooked poultry, unpasteurized milk, contaminated water
Clostridium botulinum—children and adults (preformed toxin)	12–72 hours	Vomiting, diarrhea, blurred vision, diplopia, dysphagia, and descending muscle weakness	Variable (from days to months). Can result in respiratory failure and death	Home-canned foods with a low acid content, improperly canned commercial foods, home-canned or fermented fish, herb-infused oils, baked potatoes in aluminum foil, cheese sauce, bottled garlic, foods held warm for extended periods of time (eg, in a warm oven)
C. botulinum—infants	3–30 days	In infants <12 months, lethargy, weakness, poor feeding, constipation, hypotonia, poor head control, poor gag and sucking reflex	Variable	Honey, home-canned vegetables and fruits, corn syrup
Clostridium perfringens (toxin)	8–16 hours	Watery diarrhea, nausea, abdominal cramps; fever is rare	24–48 hours	Meats, poultry, gravy, dried or precooked foods, time- and/or temperature-abused food
Cryptosporidium	5–8 days	Diarrhea (usually watery), stomach cramps, upset stomach, slight fever	May remit and relapse over weeks to months	Drinking water. Food contaminated with human fecal material
Cyclospora	Ave. 7 days	Diarrhea (usually watery), loss of appetite, weight loss, stomach cramps, nausea, vomiting, fatigue	May remit and relapse over weeks to months	Fresh herbs and produce (eg, raspberries, basil, lettuce)

Continued

Table 12-3 Bacteria, Bacterial Toxin, Virus, Parasite, and Allergen Sources and Presentation of Illnesses—cont'd

Agent	Incubation Period	Symptoms	Symptom Duration	Common Sources
Enterohemorrhagic *E. coli* (EHEC) including *E. coli* 0157:H7 and other Shiga toxin–producing *E. coli* (STEC)	1–8 days	Severe diarrhea that is often bloody, abdominal pain and vomiting. Usually, little or no fever is present. More common in children <4 years of age	5–10 days	Undercooked beef especially hamburger, unpasteurized milk and juice, raw fruits and vegetables (eg, sprouts), salami (rarely), and contaminated water
Enterotoxigenic *E. coli*	1–3 days	Watery diarrhea, abdominal cramps, some vomiting	3 to >7 days	Food or water contaminated with human feces
Giardia	7–10 days	Diarrhea, stomach cramps, gas	Days to weeks	Drinking water. Food contaminated with human fecal material
Hepatitis A	Average 30 days (range 15–50 days)	Diarrhea, dark urine, jaundice, and flu-like symptoms (ie, fever, headache, nausea, and abdominal pain)	Variable (2 weeks–3 months)	Food or water contaminated with human fecal material, including shellfish. Ready to eat foods touched by an infected food worker.
Listeria monocytogenes	9–48 hours For GI symptoms, 2–6 weeks for invasive disease	Fever, muscle aches, and nausea or diarrhea. Pregnant women may have mild flu-like illness, and infection can lead to premature delivery or stillbirth. Elderly or immunocompromised patients may have bacteremia or meningitis.	Variable	Fresh soft cheeses, unpasteurized or inadequately pasteurized milk, ready-to-eat deli meats, hot dogs, contaminated fruits and vegetables
Monosodium Glutamate (MSG)	<1 hour	Burning sensation, chest tightness, flushing, dizziness, headache, nausea	<1 day	Chinese foods
Norovirus (and other *caliciviruses*)	12–48 hours	Nausea, vomiting, cramping, diarrhea, fever, myalgia and some headache. Diarrhea is more prevalent in adults. Vomiting is more prevalent in children	12–60 hours	Food or water contaminated with human fecal material, including shellfish. Ready to eat foods touched by an infected food worker
Paralytic Shellfish Poisoning	<3 hours	Diarrhea, nausea, vomiting, parasthesias of mouth, lip, weakness, dysphagia, dysphonia, respiratory paralysis	Days	Scallops, mussels, clams, cockles
Salmonella spp. (nontyphi)	1–3 days	Diarrhea, fever, abdominal cramps, vomiting	4–7 days	Contaminated eggs, unpasteurized milk or juice, cheese, contaminated raw fruits and vegetables
Scombroid (histamine)	<3 hours	Flushing, rash, burning sensation of skin,	3–6 hours	Fish: Bluefin, tuna, skipjack, mackerel, marlin, escolar, and mahi mahi.

Shigella spp.	1–4 days	Abdominal cramps, fever and diarrhea. Stools may contain blood and mucus	4–7 days	Food or water contaminated with human fecal material. Ready to eat foods touched by an infected food worker
Staphylococcus aureus (preformed enterotoxin)	1–6 hours	Sudden onset of severe nausea and vomiting. Abdominal cramps. Diarrhea and fever may be present	24–48 hours	Unrefrigerated or improperly refrigerated meats, potato and egg salads, cream pastries
Vibrio cholerae (toxin)	24–72 hours	Profuse watery diarrhea and vomiting, which can lead to severe dehydration and death within hours	3–7 days. Causes life-threatening dehydration	Contaminated water, fish, shellfish, street-vended food, typically from Latin America or Asia
Vibrio parahaemolyticus	2–48 hours	Watery diarrhea, abdominal cramps, nausea, vomiting	2–5 days	Raw or undercooked seafood such as fish or shellfish
Vibrio vulnificus	1–7 days	Vomiting, diarrhea, abdominal pain, bacteremia, and wound infections. More common in the immunocompromised or in patients with chronic liver disease (presenting with bullous skin lesions). Can be fatal in patients with liver disease and the immunocompromised	2–8 days	Undercooked or raw shellfish, especially oysters; other contaminated seafood, and open wounds exposed to sea water.
Yersinia enterocolytica and *Y. pseudotuberculosis*	24–48 hours	Appendicitis-like symptoms (diarrhea and vomiting, fever, and abdominal pain) occur primarily in older children and young adults. May have a scarlatiniform rash with *Y. pseudotuberculosis*	1–3 weeks, usually self-limiting	Undercooked pork, unpasteurized milk, tofu, contaminated water. Infection has occurred in infants whose caregivers handled chitterlings.

Adapted from Centers for Disease Control and Prevention, US Food and Drug Administration, and Washington State Department of Health information (CDC, 2004; WSDOH, 2009; USFDA, 2015).

Foodborne Chemical Contamination

In addition to the pathogens, toxins, and allergens listed in Table 12-3, there are many chemicals which can be introduced to foods either accidently during production or transportation, or intentionally. One such example occurred in the summer of 1955 when an unusual outbreak was observed by pediatricians in western Japan. Dozens of children, mostly under 1-year old, were having symptoms including anorexia, darkened skin pigmentation, fever, and gastrointestinal problems. Antibiotics were prescribed, but health outcomes did not improve. One consistent link was being bottle fed using a popular brand of dried milk, Morinaga MF milk formula. Dr. Eiji Hamamoto, a pediatric researcher at Okayama University Hospital, suspected the illnesses might be linked to metal or metalloid poisoning, specifically suggesting it could be arsenic. Confirmation came after arsenic was discovered in the liver tissue and hair of a deceased infant. Following the postmortem discovery, Morinaga MF dried milk was fed to mice for 7–9 days. Detectable amounts of arsenic were found in the dead mice's livers. The further sale of the milk product was banned in Japan and a large recall ensued. However, it was too late for over 100 children who died from arsenic poisoning. It took many years to realize the true impact of this tragic event. Over 13,000 were exposed; 337 experienced developmental retardation, 129 have various disabilities; 103 have mental disorders; and 33 experience epilepsy (Dakeishi et al., 2006).

The arsenic contamination of the Morinaga MF milk formula is an example of the interconnectedness of sociopolitical issues and public health. Japan was early in an economic, post-World War II recovery surge, and all industries were under extreme pressure and competition. Quality control of raw materials and food safety were not a priority. A low-grade tainted product, disodium phosphate, had been added to the cow's milk to stabilize acidity. It contained between 5% and 8% arsenous acid (arsenic) (Hamamoto, 1957; Yamashita et al., 1972).

Foodborne Bioterrorism

The accidental introduction of arsenic into the Morinaga MF milk formula illustrates the vulnerability of food and water sources. The risk of intentional food contamination with a biological agent may be considered an act of bioterrorism. Bioterrorism is defined as "the deliberate release of viruses, bacteria, or other germs (agents) used to cause illness or death in people, animals, or plants" (CDC, 2007). The first large-scale attempt at using food in an act of bioterrorism in the United States occurred in 1984. Outside the Dalles, Oregon, the followers of Bhagwan Shree Rajneesh had established a commune. Local land-use laws limited the planned expansion of the commune, so the Rajneeshees decided to attempt to sicken as many townspeople as possible to sway the election results in their favor. They discreetly contaminated 10 local restaurant salad bars with *Salmonella*, resulting in a large outbreak of *Salmonella typhimurium*. As a result, 751 associated illnesses were discovered during the investigation. Their county jurisdiction typically sees five or less cases per year. Although the cult was suspected of carrying out the attack, there was no initial evidence. It was not until their compound was later raided in an unrelated investigation that a vial of *S. typhimurium* was discovered. The strain was a perfect match to the one used to carry out the attacks. Cult members subsequently confessed to the crime (Torok et al., 1997).

Unlike intentional airborne releases, intentional food contamination may result in the sudden onset of acute symptoms, or as in the cases of the Dalles and Morinaga MF contaminations, symptoms may be more insidious. This makes investigation and detection for law enforcement agencies more complex.

Prevention and Preparedness

Safeguarding food safety requires risk assessments throughout the entire food chain, from "farm to fork." Farm animals can be exposed to pathogenic organisms through their natural environment or through industrial farming operations. Animal feed can be contaminated with a variety of toxins and bacteria, potentially leading to human illness from the derived food products. Milk can be contaminated throughout collection, processing, and delivery. Fruits and vegetables can also be contaminated at the farm or cross-contaminated at any point prior to being on the table. Microorganisms are everywhere in the environment. Most are found in soil and water, feces, animals and fish, vectors such as rats, mice, and insects, and from the nose, mouth, hands, and skin of people. Global transportation of food commodities is complex, and international safety rules may vary. As a result, all food products must be protected by practices beginning at the farm, throughout slaughtering and/or subsequent processing, during food transport and delivery, in food handling and preparation, and during food storage and reheating. There are many places during these processes where pathogenic organism can be introduced, and given the right environment to promote growth, they can lead to human illnesses. The resulting illnesses can have a disproportionate impact on the very young, very old, and others who have compromised immune function. Foodborne illnesses also place a strain on public health and healthcare systems, and even on national economies. However, most foodborne disease is preventable with proper food handling (see Fig. 12-3).

There are many food safety campaigns. The World Health Organization has a successful program called the Five Keys to Safer Food. The program presents five simple food safety measures with three to five bullets for each (WHO, 2015):

1. Keep clean
   - **a.** Wash your hands before handling food and often during food preparation.
   - **b.** Wash your hands after going to the toilet.
   - **c.** Wash and sanitize all surfaces and equipment used for food preparation.
   - **d.** Protect kitchen areas and food from insects, pest and other animals.
2. Separate raw and cooked
   - **a.** Separate raw meat, poultry and seafood from other foods.
   - **b.** Use separate equipment and utensils such as knives and cutting boards for handling raw foods.
   - **c.** Store food in containers to avoid contact between raw and prepared food.
3. Cook thoroughly
   - **a.** Cook food thoroughly, especially meat, poultry, eggs and seafood.
   - **b.** Bring foods such as like soups and stews to boiling to make sure that they have reached 70°C (160°F). For meat and poultry, make sure that juices are clear, not pink. Ideally, use a thermometer.

FIGURE 12-3 Handwashing image courtesy of the United States Department of Agriculture, Food Safety and Inspection Service.

   c. Reheat cooked food thoroughly.
4. Keep food at safe temperatures
   a. Do not leave cooked food at room temperature for more than 2 hours.
   b. Refrigerate promptly all cooked and perishable food (preferably below 5°C or 40°F).
   c. Keep cooked food piping hot (more than 60°C or 140°F) prior to serving.
   d. Do not store food too long even in the refrigerator.
   e. Do not thaw frozen food at room temperature.
5. Use safe water and raw materials
   a. Use safe water or treat it to make it safe.
   b. Select fresh and wholesome foods.
   c. Choose foods processed for safety, such as pasteurized milk.
   d. Wash fruits and vegetables, especially if eaten raw.
   e. Do not use food beyond its expiry date.

Note: Fahrenheit temperatures are not on the WHO materials, but were added to this summary for the benefit of those not using Celsius. Although the scientific community has moved to Celsius, food safety programs in the United States and associated territories (Puerto Rico, Guam, US. Virgin Islands, etc.), as well as some Caribbean nations (Bahamas, Belize, the Cayman Islands) still use Fahrenheit.

Foodborne Outbreak Response

A foodborne outbreak can occur when industrial food safety standards are not enforced or properly instituted, or when there is improper food handling. An effective outbreak

response involves a multidisciplinary public health team to investigate and resolve the occurrence and to safeguard against a recurrence. There are four key disciplines necessary to accomplish a successful investigation:

1. Epidemiologists study the distribution of the disease.
2. Microbiologists isolate and study the potential causative organisms or substances.
3. Sanitarians or environmental health specialists examine the processes contributing to the outbreak.
4. Regulatory compliance officers or inspectors ensure that violations are cited and corrected.
   CDC (2015).

Additional specialists are added to the response as circumstances dictate. The focus of the outbreak investigation is dynamic and may change to include shifting between the epidemiological investigation, laboratory studies and findings, sanitarian or environmental health assessments, and regulatory investigation findings.

Interviews are a key component of the epidemiological investigation for most foodborne outbreak investigations. The questions for those who are or have been ill include demographics such as date of birth, gender, race, and ethnicity. A detailed multiday food history is essential and must include foods prepared in the home as well as commercially purchased. A travel history is taken, including all recent trips from international to local or regional locations. Descriptions of any contact with nonlocal visitors may also be relevant. A clinical history is taken to include the symptoms, date of onset, and duration of illness. Any diagnostic testing and treatment must be noted. Also, any conditions which could increase risk, such as pregnancy or immune-compromising conditions, should be documented. It is important to assess the risk an interviewee may pose to others as well. Those who work in the food industry, healthcare, or daycare centers may have exposed others. The balance of the interview questions are typically concerning common locations visited and exposures which may link ill individuals.

The initial epidemiological information, including interview results, is combined to identify likely sources. The epidemiologic information is combined with environmental health assessment data such as food sample testing and process flow charts to develop a hypothesis. This should be done as early in the investigation as possible based upon the person, place, and time commonalities of affected persons. The array of complex processes involved in a foodborne outbreak investigation must be accomplished with speed and accuracy so that control measures can be implemented (Fig. 12-4).

Control measures will include cleanup of the environments identified as likely sources for contamination. This may be necessary throughout the path downstream from the contamination. For example, vegetables that are found to have bacteriologic contamination may then contaminate preparation tables and cross-contaminate other raw vegetables. If the identified pathogen is hepatitis, mass vaccination may be instituted for people who have consumed products within the infective period. Recall of contaminated food products may need to be implemented if the food is processed and then marketed. Government agencies may choose to allow for companies to voluntarily recall products or

FIGURE 12-4 A Field Epidemiology Training Program resident at work in the laboratory. The resident is seated at his microscope and carefully analyzing a bottle containing a tissue culture solution during what could have been an outbreak investigation. *Photo courtesy of the Centers for Disease Control and Prevention.*

may mandate recall, depending on the scope and scale of the illness, the collaboration of industry, and the applicable regulations. Public messaging regarding any recall will be made to stores as well as to the general public through multiple media channels and must include information on lot numbers, dates of possible purchasing, locations of possible purchasing, and instructions on what to do with recalled products (discard or return to store). Recommendations for healthcare providers will also need to be distributed to raise the level of suspicion for diagnosing and treating identified illness and potentially to initiate active monitoring for cases. If contamination has occurred in institutionalized settings such as long-term care facilities and other regulated congregate settings, other measures may need to be taken.

Summary

Foodborne outbreaks are among the most common public health threats in the world. Most are either unreported or underreported. Although most outbreaks are relatively

small and self-limited, large outbreaks sometimes occur. Some outbreaks rise to the level of a public health emergency, requiring support from other public health professionals outside the affected jurisdiction. While the most common cause is inappropriate food handling or storage, there are risks associated with industrial processes and transportation which could result in large-scale outbreaks. There is also a constant threat of intentional food contamination as an act of bioterrorism. The response to any size of outbreak must be carried out with two key characteristics, speed and accuracy. Neither can be compromised. According to the Council to Improve Foodborne Outbreak Response, the emphasis on speed and accuracy is directed at:

1. stopping the outbreak quickly and preventing additional illnesses
2. preventing future outbreaks by using the lessons learned
3. identifying new threats and vulnerabilities in food safety
4. maintaining public confidence in the food supply and public health
5. empowering the public to protect themselves from foodborne threats *CIFOR (2014)*.

Websites

Centers for Disease Control and Prevention (CDC), Foodborne Illness Homepage. http://www.cdc.gov/foodsafety/facts.html.

Centers for Disease Control and Prevention (CDC), Diagnosis and Management of Foodborne Illnesses: A Primer for Physicians and Other Health Care Professionals. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm.

Council to Improve Foodborne Outbreak Response (CIFOR). http://www.cifor.us/.

European Food Safety Authority. http://www.efsa.europa.eu/.

U.S. Food and Drug Administration, Bad Bug Book: Handbook of Foodborne Pathogenic Microorganisms and Natural Toxins. http://www.fda.gov/downloads/Food/FoodborneIllnessContaminants/UCM297627.pdf.

U.S. Food and Drug Administration, Foodborne Illness & Contaminants. http://www.fda.gov/Food/FoodborneIllnessContaminants/default.htm.

U.S. National Library of Medicine, MedlinePlus, Foodborne Illness. http://www.nlm.nih.gov/medlineplus/foodborneillness.html.

World Health Organization (WHO), Food Safety. http://www.who.int/topics/food_safety/en/.

World Health Organization (WHO), The Five Keys to Safer Food Programme. http://www.who.int/foodsafety/consumer/5keys/en/.

References

Adak, G.K., Long, S.M., O'Brien, S.J., 2002. Trends in indigenous foodborne disease and deaths, England and Wales: 1992 to 2000. Gut 51, 832–841.

Centers for Disease Control and Prevention (CDC), April 16, 2004. Diagnosis and management of foodborne illnesses, a primer for physicians and other health care professionals. MMWR 53 (RR04), 1–33. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5304a1.htm.

Centers for Disease Control and Prevention (CDC), 2007. Emergency Preparedness and Response: What Is Bioterrorism? Available at: http://emergency.cdc.gov/bioterrorism/overview.asp.

Centers for Disease Control and Prevention (CDC), 2012. Multistate Outbreak of Listeriosis Linked to Whole Cantaloupes from Jensen Farms, Colorado. Outbreak Highlights, August 27, 2012 (FINAL Update Addendum). Available at: http://www.cdc.gov/listeria/outbreaks/cantaloupes-jensen-farms/index.html.

Centers for Disease Control and Prevention (CDC), January 8, 2014. Estimates of Foodborne Illness in the United States. CDC 2011 Estimates: Findings. Available at: http://www.cdc.gov/foodborneburden/2011-foodborne-estimates.html.

Centers for Disease Control and Prevention (CDC), 2015. Key Players in Foodborne Outbreak Response. Available at: http://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/key-players.html.

Council to Improve Foodborne Outbreak Response (CIFOR), 2014. Guidelines for Foodborne Disease Outbreak Response, second ed. Council of State and Territorial Epidemiologists, Atlanta. Available at: http://www.cifor.us/.

Dakeishi, M., Murata, K., Grandjean, P., October 31, 2006. Long-term consequences of arsenic poisoning during infancy due to contaminated milk powder. Environ. Health 5, 31. Published online. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1635412/#B14.

ElBoghdady, D., October 19, 2011. Unsanitary Packing Probably Led to Cantaloupe Outbreak. The Washington Post. Available at: http://www.washingtonpost.com/business/economy/unsanitary-packing-probably-led-to-cantaloupe-outbreak/2011/10/19/gIQAb2pjyL_story.html.

Elliot, D., October 3, 2011. For Listeria Victims, Sudden Turns for the Worse. The Huffington Post. Available at: http://www.huffingtonpost.com/2011/10/03/for-listeria-victims-sudd_n_991877.html.

European Commission (EU), 2013. Sanitary and Phytosanitary (SPS) Issues. Available at: http://trade.ec.europa.eu/doclib/docs/2013/april/tradoc_150986.pdf.

Flynn, D., April 4, 2012. The 10 Deadliest Outbreaks in U.S. History—Revisited. Food Safety News. Available at: http://www.foodsafetynews.com/2012/04/the-ten-deadliest-outbreaks-in-history-revisited/#.VdElHU2FNjD.

Hamamoto, E. (Ed.), 1957. Report of Arsenic Poisoning Incident Due to Powdered Milk in Okayama Prefecture (In Japanese). Okayama Prefectural Government, Okayama.

Kirk, M., Ford, L., Glass, K., Hall, G., November 2014. Foodborne illness, Australia, circa 2000 and circa 2010. Emerg. Infect. Dis. 20 (11), 1857–1864. http://dx.doi.org/10.3201/eid2011.131315.

Kosek, M., Bern, C., Guerrant, R.L., 2003. The global burden of diarrheal disease, as estimated from studies published between 1992 and 2000. Bull. World Health Organ 81, 197–204.

Scallan, E., Hoekstra, R.M., Angulo, F.J., Tauxe, R.V., Widdowson, M.A., Roy, S.L., Jones, J.L., Griffin, P.M., January 2011. Foodborne illness acquired in the United States–major pathogens. Emerg. Infect. Dis. 17 (1), 7–15. http://dx.doi.org/10.3201/eid1701.091101p1.

Torok, T.J., Tauxe, R.V., Wise, R.P., Livengood, J.R., Sokolow, R., Mauvais, S., Birkness, K.A., Skeels, M.R., Horan, J.M., Foster, L.R., August 6, 1997. A large community outbreak of salmonellosis caused by intentional contamination of restaurant salad bars. JAMA 278 (5), 389–395.

U.S. Food and Drug Administration (USFDA), January 9, 2012. Information on the Recalled Jensen Farms Whole Cantaloupes. Final Update on Multistate Outbreak of Listeriosis Linked to Whole Cantaloupes. Available at: http://www.fda.gov/Food/RecallsOutbreaksEmergencies/Outbreaks/ucm272372.htm.

U.S. Food and Drug Administration (USFDA), 2015. Foodborne Illnesses: What You Need to Know. Available at: http://www.fda.gov/food/resourcesforyou/consumers/ucm103263.htm.

Vanderveen, C., September 26, 2013. Colo. Farmers Arrested in Listeria Outbreak That Killed 33. KUSA-TV, Denver. Available at: http://www.usatoday.com/story/news/nation/2013/09/26/colorado-cantaloupe-listeria/2877913/.

Washington State Department of Health (WSDOH), 2009. Foodborne Illness: Common Agents Causing Foodborne Illness, Grouped by Symptoms. Available at: http://www.doh.wa.gov/portals/1/documents/5100/foodchart.pdf.

World Health Organization (WHO), 2015. The Five Keys to Safer Food Programme. Available at: http://www.who.int/foodsafety/consumer/5keys/en/.

Yamashita, N., Doi, M., Nishio, M., Hojo, H., Tanaka, M., October 1972. Recent observations of Kyoto children poisoned by arsenic tainted "Morinaga Dry Milk" (author's transl). Nihon Eiseigaku Zasshi 27 (4), 364–399.

13

Heat Waves

OBJECTIVES

- Define types of heat injuries and illnesses.
- Explain how the body manages excessive heat.
- Describe the risk factors for those who are most vulnerable to excessive heat.
- List environmental factors that contribute to the severity of heat waves.
- Describe how a community can reduce the impact of severe heat conditions.
- Explain the steps in an effective local government response to a heat wave.
- Identify triggers used to activate heat wave response activities.
- Describe mistakes historically made by government in managing heat waves.
- Explain the content of and delivery methods for heat warnings shared with vulnerable populations.
- List the practical steps individuals should take to reduce the risk of heat injury.

Introduction: European Heat Wave, 2003

A long scorching European summer took a dreadful turn for the worst in August 2003. By the end of the month, it was evident that this would be the worst weather-related health disaster to hit Western Europe in centuries. Higher-than-normal temperatures began in May, and by the end of August the average temperatures were about 30% higher than normal for the season. This temperature increase was accompanied by above normal number of days of sunshine and below normal rainfall and humidity in regions where rain and clouds are the norm during the summer months (Rebetez et al., 2006). High temperatures of 95–104°F (35–40°C) were regularly recorded in July and August. These conditions resulted in more than 25,000 fires across Western Europe which destroyed over 1.6 million acres (>647,000 ha) and cost billions of euros (United Nations Environment Program, 2004). In Portugal and Spain, wildfires raged out of control for weeks. Thousands of firefighters from across Europe deployed to bring the fires under control with equipment on loan from as far away as Russia (CNN, 2003).

Although those in the rural areas of Europe struggled with the drought, heat, and fires, the human toll in the cities was also mounting. One of the hardest hit cities was Paris. It is impossible to know when the first heat wave fatalities began that summer. Those at greatest risk have other conditions and complications exacerbated by the heat. The cause of death among initial casualties in Paris was likely attributed to preexisting conditions and not directly to heat. Many casualties were elderly, homebound, and lived alone. Sometimes several days passed before the deceased were found in their homes after succumbing to the heat. The normally mild summer temperatures of Paris usually top out in July

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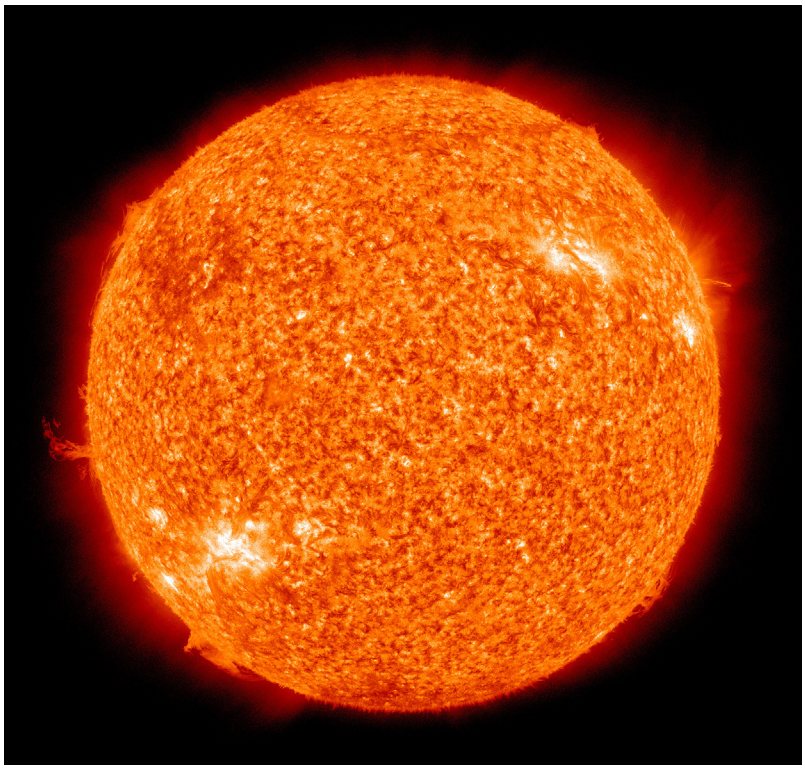
and August at about 75°F (24°C). As a result, air conditioners are not commonplace. When the temperatures in August 2003 exceeded 100°F (38°C) for nearly 2 weeks straight, the morbidity and mortality attributable to the heat quickly rose (Fig. 13-1). A daily surge of over 150 patients was experienced by Parisian healthcare facilities. A 130% mortality increase was observed above what is normally expected in the month of August across the city (Hemon and Jougla, 2003). Over one-third (35%) of these fatalities occurred in homes, 42% occurred in hospitals, and the remaining 19% occurred in long-term care facilities, most of which did not have air conditioning (Dhainaut et al., 2004).



The Sun photographed by the Atmospheric Imaging Assembly (AIA 304) of NASA's Solar Dynamics Observatory on August 31, 2010. *Image courtesy of the US National Aeronautics and Space Administration.*

A variety of controversies emerged from the tragic events in Paris. Questions were raised concerning the response of government officials. A full week had passed during the peak of the heat wave before officials acknowledged the problem and declared an emergency. Socialist Party officials blamed the administration of Prime Minister Jean-Pierre Raffarin and asked for the resignation of Health Minister Jean-Francois Mattei. The prime minister's office responded with charges that the establishment of a 35-hour workweek by the Socialist Party was responsible for reducing the number of healthcare workers available to manage the crisis. In the end, Dr. Lucien Abenhaim, who served as the Director General for Health, submitted his resignation. This action would be comparable to the resignation of

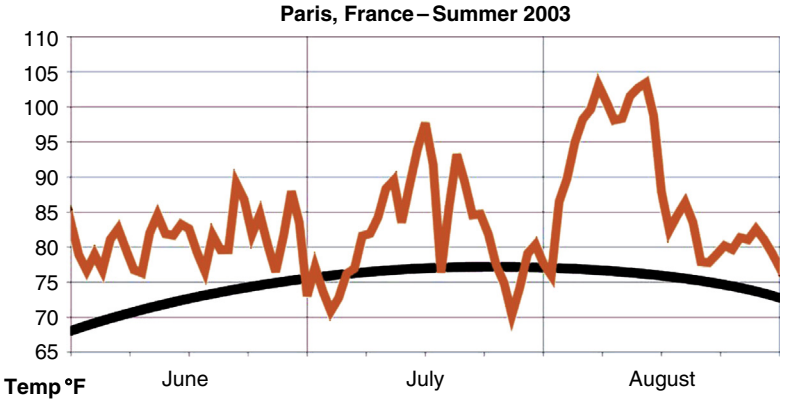


FIGURE 13-1 Actual versus average daily maximum temperatures in Paris, France, 2003. *Image courtesy of the US Environmental Protection Agency, (EPA, 2006).*

the US Surgeon General. Following the resignation of Dr. Abenhaim, Prime Minister Raffarin blamed the heat wave's impact on the larger community's state of affairs. He pointed out in interviews with the French press that over half the fatalities occurred outside healthcare facilities, and many who were brought to local emergency departments were in such poor condition by the time they arrived that little could be done to save them. He shifted the blame instead to global warming and the general public. August is a popular time for family vacations. Many friends and relatives of elderly victims who would normally check in on them were out of town during the heat wave (Tagliabue, 2003).

In reality, *all* of the issues raised by government leaders and party officials contributed to the tragic outcomes. Most buildings in Paris do not have air conditioning. The city is simply not designed to protect the population from excessive temperatures. Public health officials failed to anticipate the impact of the heat wave and institute community measures and public warnings. The healthcare system was not adequately prepared and staffed to handle such an emergency. It was vacation season and many elderly residents did not have the social support they would normally have checking on them. These and other factors contributed to a death toll across Europe reported to exceed 30,000. Nearly half of the fatalities were in France. The others were throughout Germany, Spain, Italy, the United Kingdom (UK), the Netherlands, Portugal, and Belgium.

Heat-Related Definitions

Heat cramps Heat cramps are muscular pains and spasms resulting from physical exertion in a hot environment. Insufficient fluid intake can increase the severity. Although heat cramps are the least severe type of heat injury, they are an early indication that the body is having trouble with the heat.

Heat exhaustion Heat exhaustion occurs when individuals physically exert themselves in a hot, humid environment and become dehydrated. As body fluids are lost through heavy sweating, blood flow to the skin begins to increase. This results in decreased blood flow to the vital organs leading to a form of mild shock. If the victim is not quickly cooled and rehydrated, a heatstroke may result.

Heat fatigue Heat fatigue refers to the state of discomfort and psychological strain from sustained heat exposure. This condition sometimes occurs when an individual has not experienced a period of gradual adjustment to the hot environment and is not acclimated.

Heat index The heat index is a number in degrees (Fahrenheit or Celsius) which tells how hot it feels when relative humidity is added to the actual air temperature. As humidity increases, the evaporation of perspiration from a person is slowed and more heat is retained. The heat index accounts for the decreased rate of evaporation and is a more accurate representation of the temperature related to human health risks.

Heatstroke Heatstroke, also called sunstroke, is a life-threatening condition. If heat exhaustion is left unchecked, the body's temperature control system will stop working. This includes the loss of the ability to sweat. The body temperature can increase so high that brain damage and death can result if the body is not cooled quickly.

Heat wave A heat wave is an extended period of excessive heat and humidity resulting in health threats to the community. There is no precise quantitative formula to define a heat wave as there are so many variables from one community or geographical region to another. A qualitative definition is simply a period of abnormal heat which generates a public response. This response may be due to the impact on human or animal health, crops, utilities, or commerce. However, for the purposes of this section, the term heat wave refers primarily to the human health threat.

Sunstroke Sunstroke is another name for heatstroke.

Urban Heat Islands (UHIs) Urban Heat Islands describe urban areas where building and road materials absorb more heat and cause urbanized areas to maintain higher temperatures than surrounding rural areas.

Wet Bulb Globe Temperature (WBGT) A composite measure of heat stress risk including direct sunlight, temperature, humidity, wind speed, sun angle and cloud cover.

Heat Waves

Heat waves are one of the most subtle yet most lethal disasters. Local infrastructure shows no damage, and commerce and travel continue with little noticeable impact. Hospitalizations and deaths slowly increase among vulnerable populations, while causes often remain attributed to conditions other than heat. Although heat emergencies do not exhibit the drama of many other disasters, they produce greater mortality than hurricanes, tornadoes, and earthquakes combined. The lack of associated drama often results in low levels of media attention, public outcry, or political will for focusing adequate attention and resources toward improving heat emergency preparedness and making it a higher priority. The worst effects of extreme heat are felt by the elderly, children, the poor, and the homeless. In addition, persons with chronic cardiovascular, pulmonary, or other chronic health conditions, as well as those with mental/behavioral health problems, are at increased risk of heat-related morbidity. Global climate change and other local environmental changes drive the likelihood of extreme heat events higher at a time when populations are increasingly at risk for heat-related illness and injury. It is important to understand effective measures to prepare for, predict, and manage heat waves.

Human Health Effects

The human body maintains an internal temperature within a very narrow range. A normal body temperature is 98.6°F (37°C), but can fluctuate in a healthy person by about 1°F (0.6°C)

over the course of a day. This normal fluctuation results from varying activity levels and normal hormonal changes. As heat increases in the body, blood vessels near the skin dilate in order to bring the blood closer to the surface to release heat. When severe, vasodilation can place additional stress on organs such as the heart, brain, and kidneys by reducing the available supply of blood needed for normal function. Vasodilation can also reduce blood pressure when the heart's output cannot compensate to normalize blood pressure. Sweat glands also become active, releasing moisture onto the skin. As sweat evaporates, more heat is dissipated through evaporation (Simon, 1993). Heat is also released through the lungs during respiration. During everyday activities and moderate temperatures, the skin and lungs can efficiently regulate internal body temperature. However, when environmental conditions or physical activity generates more heat than the body can regulate, there is increasing risk for heat-related illnesses. The heat burden of the body significantly increases when engaged in physical activity. During times of heavy exertion, additional energy is expended, and nearly 75% of that energy is directly converted to heat rather than energy (Mellion and Shelton, 1997).

Risk Factors for Heat Illness and Injury

Physical Factors

- elderly (age >65)
- infants (age <1)
- physically disabled
- mentally/behaviorally impaired
- engaged in outdoor exercise or work
- users of alcohol or illegal drugs
- users of certain prescription medications (eg, medications for high blood pressure, motion sickness, gastrointestinal medications containing atropine, sleeping pills, antidepressants, antihistamines, and Parkinson's disease)

Social Factors

- low income
- homeless
- socially isolated
- urban residence
- poor access to healthcare or cooling shelters

Dehydration is also a critical risk factor for heat illness. If net fluid loss exceeds only 3% of normal levels in the body, the risk of heat illness quickly increases because thermoregulatory mechanisms are impaired (ASMA, 2005). Fluid loss can occur due to inadequate water consumption during physical activity or simply with extended exposure to low humidity. Other injuries or illnesses may contribute to fluid loss. These include shock, trauma, burns (including sunburn), gastrointestinal tract disease causing diarrhea or vomiting, malnutrition, and hyperglycemia from chronic conditions such as diabetes. Fluid loss is further complicated by consumption of diuretics such as alcohol- or caffeine-containing beverages. Some medications cause individuals to sweat or urinate more and

Table 13-1 Heat Index Risk Categories

Category	Heat Index	Possible Heat Illnesses for Exposed Vulnerable Populations
Extreme danger	130°F or higher (54°C or higher)	Heatstroke likely with prolonged exposure
Danger	105–129°F (41–54°C)	Heat exhaustion/muscle cramps likely, heatstroke possible
Extreme caution	90–104°F (32–40°C)	Heat exhaustion/muscle cramps possible
Caution	80–89°F (27–32°C)	Heat fatigue possible

can contribute to dehydration as well. These drugs include motion sickness and gastrointestinal medications containing atropine, sleeping pills, antidepressants, antihistamines, diuretics, blood pressure medications, and Parkinson's disease medications.

The effects of extreme heat on the body worsen as humidity rises, which slows the evaporation of moisture from the skin, challenging the body's effort to maintain a normal internal temperature. The US National Weather Service (NWS) has developed a heat index to more accurately reflect the apparent temperature or the temperature experienced by the body when humidity is factored into the conditions (see Table 13-2) (NOAA, 1994). In direct sunlight, the heat index can increase by 15°F. Likewise, conditions which include high temperatures, low humidity, and strong winds can rapidly dehydrate the body. The NWS Heat Index Chart (see Table 13-1) does not fully account for the effect of direct sunlight or dry, windy conditions. The heat index chart calculations are based on a variety of assumptions, including environmental parameters such as shady and slightly windy conditions. These assumptions reduce the precision of the heat index as a predictive tool. However, the chart does provide a simple measure of risk, particularly among higher risk groups. This basic tool provides triggers for instituting community response measures during a heat wave.

Heat is particularly challenging in urban areas. Urban heat islands (UHIs) are created through heat retention in the built environment. Brick, concrete, asphalt, and other surfaces ubiquitous in an urban environment tend to hold heat and release it throughout the evening and nighttime hours, and therefore temperatures remain elevated for a longer period of time. A modern city with a population of 1 million people can maintain daytime temperatures that are 1.8–5.4°F (1–3°C) warmer than in surrounding rural areas. Since building and street surfaces retain more heat, a city can be up to 22°F (12°C) warmer than it is in nonurban areas (EPA, 2015). Exposure to heat from these warmed surfaces is through both conductive and radiant heat exchange. Conductive heat transfer is through direct contact with the heated surfaces and radiant heat transfer is heat given off surfaces in waves. Height and spacing of buildings, air pollution and construction material may all contribute to the impact of UHIs.

Heat illness can range from heat cramps or heat exhaustion to heatstroke. These heat-related illnesses typically occur when the body is exerted beyond its physical capacity during exercise with poor hydration and with essential electrolyte depletion. Acclimatization to heat effects can occur over time but individuals who have not acclimatized can have immediate fluid and electrolyte shifts resulting in illness and death.

Table 13-2 US National Weather Service Heat Index (HI) Charts

Temperature °F — Relative Humidity (%)

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
80	77	78	78	79	79	79	80	80	80	81	81	82	82	83	84	84	85	86	86	87
81	78	79	79	79	79	80	80	81	81	82	82	83	84	85	86	86	87	88	90	91
82	79	79	80	80	80	80	81	81	82	83	84	84	85	86	88	89	90	91	93	95
83	79	80	80	81	81	81	82	82	83	84	85	86	87	88	90	91	93	95	97	99
84	80	81	81	81	82	82	83	83	84	85	86	88	89	90	92	94	96	98	100	103
85	81	81	82	82	82	83	84	84	85	86	88	89	91	93	95	97	99	102	104	107
86	81	82	83	83	83	84	85	85	87	88	89	91	93	95	97	100	102	105	108	112
87	82	83	83	84	84	85	86	87	88	89	91	93	95	98	100	103	106	109	113	116
88	83	84	84	85	85	86	87	88	89	91	93	95	98	100	103	106	110	113	117	121
89	84	84	85	85	86	87	88	89	91	93	95	97	100	103	106	110	113	117	122	
90	84	85	86	86	87	88	89	91	92	95	97	100	103	106	109	113	117	122	127	
91	85	86	87	87	88	89	90	92	94	97	99	102	105	109	113	117	122	126	132	
92	86	87	88	88	89	90	92	94	96	99	101	105	108	112	116	121	126	131		
93	87	88	89	89	90	92	93	95	98	101	104	107	111	116	120	125	130	136		
94	87	89	90	90	91	93	95	97	100	103	106	110	114	119	124	129	135	141		
95	88	89	91	91	93	94	96	99	102	105	109	113	118	123	128	134	140			
96	89	90	92	93	94	96	98	101	104	108	112	116	121	126	132	138	145			
97	90	91	93	94	95	97	100	103	106	110	114	119	125	130	136	143	150			
98	91	92	94	95	97	99	102	105	109	113	117	123	128	134	141	148				
99	92	93	95	96	98	101	104	107	111	115	120	126	132	138	145	153				
100	93	94	96	97	100	102	106	109	114	118	124	129	136	143	150	158				
101	93	95	97	99	101	104	108	112	116	121	127	133	140	147	155					
102	94	96	98	100	103	106	110	114	119	124	130	137	144	152	160					
103	95	97	99	101	104	108	112	116	122	127	134	141	148	157	165					
104	96	98	100	103	106	110	114	119	124	131	137	145	153	161						
105	97	99	102	104	108	112	116	121	127	134	141	149	157	166						
106	98	100	103	106	109	114	119	124	130	137	145	153	162	172						
107	99	101	104	107	111	116	121	127	134	141	149	157	167							
108	100	102	105	109	113	118	123	130	137	144	153	162	172							
109	100	103	107	110	115	120	126	133	140	148	157	167	177							
110	101	104	108	112	117	122	129	136	143	152	161	171								
111	102	106	109	114	119	125	131	139	147	156	166	176								
112	104	107	111	115	121	127	134	142	150	160	170	181								
113	104	108	112	117	123	129	137	145	154	164	175									
114	105	109	113	119	125	132	140	148	158	168	179									
115	106	110	115	121	127	134	143	152	162	173	184									
116	107	111	116	122	129	137	146	155	166	177										
117	108	112	118	124	132	140	149	159	170	181										
118	108	113	119	126	134	142	152	162	174	186										
119	109	114	121	128	136	145	155	166	178											
120	110	116	122	130	138	148	158	170	182											
121	111	117	124	132	141	151	162	174	187											
122	111	118	125	134	143	154	165	178												
123	112	119	127	136	146	157	169	182												
124	113	120	129	138	148	160	172													
125	114	121	130	140	151	163	176													

Extreme Danger	Heat stroke likely.
Danger	Sunstroke, muscle crumps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	Fatigue possible with prolonged exposure and/or physical activity.

Temperature °C — Relative Humidity (%)

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
23.3																72	72	73	73	74	74
23.9															72	72	73	73	74	74	75
24.4														72	72	73	73	74	74	75	75
25.0													72	72	73	73	74	74	75	75	76
25.6												72	73	73	74	74	75	75	76	76	77
26.1											72	73	73	74	74	75	76	76	77	77	78
26.7										72	72	73	73	74	74	75	76	76	77	78	78
27.2									72	72	73	73	74	74	75	76	77	77	78	78	79
27.8									72	73	73	74	75	75	76	77	77	78	79	79	80
28.3								72	73	73	74	74	75	76	77	78	78	79	80	80	81
28.9								72	73	73	74	75	75	76	77	78	78	79	80	80	81
29.4							72	72	73	74	75	75	76	77	78	78	79	80	81	81	82
30.0							72	73	74	74	75	76	77	78	78	79	80	81	81	82	83
30.6						72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84
31.1					72	72	73	74	75	75	76	77	78	79	80	81	81	82	83	84	85
31.7					72	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86
32.2					72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86
32.8					73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87
33.3					73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88
33.9					74	75	76	77	78	79	80	80	81	82	83	84	85	86	87	88	89
34.4					74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
35.0					75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
35.6					75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92
36.1					76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93
36.7					76	77	78	79	80	82	83	84	85	86	87	88	89	90	91	93	94
37.2					76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94
37.3					77	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95
38.3					77	79	80	81	82	83	86	86	87	88	89	90	92	93	96	95	96
38.9					78	79	80	81	83	86	85	86	87	89	90	91	92	96	95	96	97
39.6					78	79	81	82	83	86	86	87	88	89	91	92	94	96	96	97	
40.0					79	80	81	82	86	85	86	88	89	90	91	93	96	96			
40.6					79	80	82	83	86	86	87	88	89	91	92	93	96	96	97		
41.1					80	81	82	86	85	86	88	89	90	91	93	94	95	97	98		
41.7					80	81	83	86	85	87	88	89	91	92	94	95	96	98			
42.2					81	82	83	85	86	87	89	90	92	93	94	96	97				
42.3					81	82	86	85	87	88	89	91	92	94	95	96	98				
43.3					81	83	86	86	87	89	90	91	93	94	96	97					
43.9					82	83	85	86	88	89	91	93	94	95	96	98					
44.4					82	86	85	87	88	90	91	94	94	96	97						
45.0					83	86	86	87	89	90	92	95	95	96	96						
45.4					83	85	86	88	89	91	92	94	96	97							
46.1					86	85	87	88	90	91	94	95	96	98							
46.7					86	86	87	89	90	92	94	95	97								
47.2					85	86	88	89	91	93	94	96	98								
47.3					85	87	88	90	92	93	95	97									
48.3					85	87	89	90	92	94	96	97									
48.9					86	88	89	91	93	94	96	98									
49.4					86	88	90	92	93	95	97										
50.0					90	89	90	92	94	96											

Heat Illness—Environmental Factors

- air temperature
- humidity
- air movement
- radiant heat
- conductive heat
- activity level
- clothing

Prevention and Preparedness

Unlike many other types of disasters, deaths from heat waves are preventable. Heat waves can be predicted and the measures needed to successfully manage their impact are well understood and inexpensive. As with most emergencies, basic infrastructure is an important first step in prevention. Adequate basic power and water supplies for an area's population is essential for daily living as well as during extreme weather events. Before the temperatures rise, it is important the community engage in preparedness activities specifically for a heat emergency. As decisions are made concerning infrastructure, particularly in urban areas, the use of cooler pavement and roofing surfaces can mitigate some of the effects of a heat wave. In addition, employers with workers potentially exposed to heat must plan ahead for possible work delays and institute policies to protect those at risk.

Urban Heat Island Mitigation

The risk of heat emergencies increases as ongoing industrialization and urbanization drive a larger proportion of the human population to settle in or near cities. A major factor in this increasing heat risk is the UHI phenomenon (see Fig. 13-2). The UHI phenomenon is

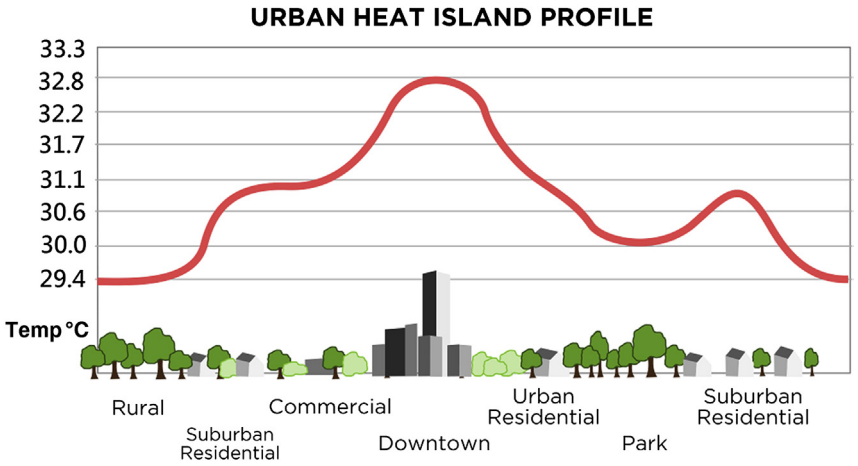


FIGURE 13-2 Urban heat island profile. *Lawrence Berkeley National Laboratory, Heat Island Group.*

worsened by the alteration of the environment resulting from urban development combined with the added heat generated by population density. The reduction in vegetation across urban areas reduces the shading of buildings and surfaces. These surfaces absorb a tremendous amount of heat and then release it slowly. As a result, nighttime urban temperatures drop more gradually than in rural areas. This keeps nighttime temperatures higher and prolongs the daily heat burden on the urban population. Another factor in increasing urban temperatures associated with vegetation is the reduction in evapotranspiration. Just as sweat evaporating from the surface of the skin provides a cooling effect; plants transpire or emit moisture through their leaves. As the water evaporates, it provides a cooling effect to the surrounding area. A reduction in vegetation also reduces these natural cooling processes.

Looking down on a city, it typically appears as a patchwork of dark-colored roofs and pavements. These darker surfaces are less reflective and absorb more heat. The widespread use of dark surface materials in urban areas creates a setting where large amounts of solar energy are absorbed and retained, driving the daytime temperatures higher and sustaining higher temperatures throughout the night. Additionally, taller structures in metropolitan areas block air movement and further reduce the rate at which these surfaces can cool. When these factors are combined with the heat generated by urban industrial and transportation activities, the accumulating heat increases urban and suburban, daytime and nighttime temperatures.

Mitigation measures to reduce UHIs are simple and offer benefits far beyond the reduction in heat. A study conducted by the US Forestry Service in Brooklyn, New York, estimated that the borough's trees, which cover just over 10% of the Brooklyn area, remove over 250 metric tons of air pollution each year (Nowak et al., 2002). This has a dual effect by improving urban public health. There is a reduction in pollutants, decreasing stress on the respiratory systems of vulnerable populations, and a reduction in temperatures through the shading and transpiration of the vegetation. This vegetation also increases the overall quality of life for urban residents by positively influencing perceptions of land use and emotions (Sheets and Manzer, 1991).

The UK Forestry Commission estimates that heat-related stress accounts for around 1100 premature deaths per year in the UK, with an estimated 8–11 extra deaths occurring each day for each degree increase in air temperature. The addition of trees in an urban environment can reduce the ambient temperature by 2–8°C. "If it is assumed, therefore, that London's trees and wider green infrastructure are preventing 2°C of additional UHI warming then the current provision of greenspaces in London may be saving 16–22 lives a day during spells of hot weather. The value of premature death averted in the UK is over £1.6 million (2010 value; Department for Transport, 2012). Purely in terms of extra deaths due to heat stress averted, London's greenspaces are collectively valued at £26.4–36.4 million" (Doick and Hutchings, 2013).

In addition to the introduction of extra vegetation, the use of cooler roof and pavement surfaces has far-reaching effects. Older roofing materials, particularly those of dark color, absorb heat and have low thermal emittance or ability to release heat. "Cool roof" materials

FIGURE 13-3 Workers apply cool roof coating on a row house in Baltimore, Maryland. *US Environmental Protection Agency.*

are light colored to reflect heat and have the ability to cool much more quickly than older roofing materials (see Fig. 13-3). These materials reduce the UHI contribution of the roof by absorbing less heat and quickly releasing absorbed heat at night. Cool roof surfaces on flat roofs are usually white to maximize reflection. This is the same principle as wearing light-colored clothing when spending time in the sun. It simply keeps you cooler by reflecting the sunlight. Not only do cool roofs reduce urban heat, they also reduce air-conditioning bills for building owners and residents and even reduce air pollution and smog formation. The same principles apply to pavement surfaces. Lighter-colored pavements (light brown, light gray, etc.) reflect more solar energy and absorb less heat. The porosity of the paved surface also contributes to the emittance of absorbed heat.

Preseason Community Preparedness Activities

The most important steps a community can take to reduce the morbidity and mortality associated with extreme heat is to identify populations at risk in advance and determine the best methods in which to provide information, and when necessary move those at risk to a safer environment. To successfully accomplish these mitigation activities requires planning. For example, many cities now have emergency shelter plans for their homeless populations during extreme heat events. Large tourist destinations such as New York City implement watering stations for drinking water and sprinklers during heat waves. However, some cities focus few to no resources toward heat emergency planning because it is a rare or unlikely event in their region. Such was the case in Paris, France, prior to the 2003 heat wave. Regions

where the occurrence of heat emergencies is less likely are more inclined to have higher mortality during a heat wave (Kalkstein and Davis, 1989). For example, if the same extreme hot weather conditions were to exist in Minneapolis, Minnesota, and Houston, Texas, mortality would likely be higher in Minneapolis. Some of this is due to infrastructure being based upon lower temperature norms. In areas where air conditioners are rarely needed, many people simply do not purchase them. The population is also less acclimated to the heat. This increases the risk of serious health outcomes from heat waves in cities which are typically cooler. The population and infrastructure are not prepared to cope with heat extremes.

No specific standards exist which prescribe appropriate heat wave preparedness and response actions. Some cities have no plans specific to heat emergencies. Even if an "all-hazards" planning approach is taken, there must be sufficient details specific to each type of potential emergency. A review of 18 city heat emergency plans found that 6 of the 18 cities had no heat emergency planning at all, and many who did gave the topic inadequate attention (Bernard and McGeehin, 2004). Effective plans must have a phased approach which addresses the measures taken by each agency leading up to the summer season. The role of each local agency must be defined, and specific measures leading up to a heat emergency must be clear. A standard warning system must be instituted and communicated in a consistent manner. Communication efforts must emphasize and target vulnerable populations. These measures may include print and broadcast public service announcements, as well as establishment of hotlines which can provide instructions for personal preparedness as well as the locations of cooling shelters. Surveillance of heat casualties must also be instituted (CDC, 1995a,b; Kizer, 2000). Heat casualty surveillance is especially challenging, since a variety of chronic and acute conditions can be exacerbated by extreme heat, but often are not attributed to the heat conditions. An effective plan will reduce the impact of a heat wave on the health of the affected population (Naughton et al., 2002; Weisskopf et al., 2002).

A good example of integrated heat wave planning can be found in the city of Milwaukee, Wisconsin. Its plan assigns the primary responsibility for development of messages and coordination of an excessive Heat Task Force to the Milwaukee City Health Department. Its primary partners include public and private agencies throughout the region who serve vulnerable populations such as the elderly, disabled, homeless, and those with mental health conditions. Their metropolitan medical society is asked to encourage healthcare providers to prepare for heat emergencies. The meteorologists in the area are encouraged to cover stories on heat illness prevention and to maintain contact with public health authorities in order to periodically update health notices. The American Red Cross maintains a 24-hour heat health tip hotline. Behavioral health organizations prepare inpatient clientele with information on heat and medications as well as support in developing emergency plans with family members. A "Heat Health Update" statement is issued to task force members 1 to 7 days prior to possible extreme heat conditions as a precursor to a heat advisory, asking them to begin anticipating emergency conditions. By adding a preemptive warning, preparations may begin prior to the arrival of the heat emergency, and an enhanced preparedness posture is achieved. Following this initial awareness, increasing heat alert levels and associated actions can be ramped up based upon meteorological thresholds (MMAHTF, 2014).

Wisconsin Excessive Heat Notification and Activation Thresholds:

- "Heat Health Update" HI values of 95 or higher during daytime hours in the next 1–7 days
- "Heat Health Advisory" HI values 100 or higher, OR daytime HI values of 95 to 99 for 4 consecutive days or more
- "Heat Health Watch or Warning" HI values equal or exceed 105, with nighttime HI minimums of 75 or higher for at least a 48-hour period, OR heat health advisory criteria of daytime HI values ranging from 100 to 104 are expected for 4 or more consecutive days

There are a variety of heat health warning systems around the world with varying approaches and sophistication (Nicholls et al., 2008; Pascal et al., 2006; Tan et al., 2004).The meteorological threshold for Milwaukee and many other cities is the heat index. Because the index assumes shady conditions with a light wind, it does not compensate for other important weather variables such as wind speed or cloud cover. The index also does not take into account the differences in human acclimatization in various regions or at different times of the year. Also not captured by the heat index is the accumulating impact heat has on human health over the course of multiple days of excessive heat.

Four Categories of Heat Health Warning Systems (Hajat et al., 2010)

- synoptic classification: temperature values categorize days of high mortality
- epidemiologic assessment: historical heat mortality data is analyzed examining the relationship between temperature and mortality by region
- temperature-humidity Index: composite measures of temperature and humidity
- physiologic classification: uses heat-budget models of the human body including the environmental stress index (ESI). ESI uses simple weather heat variables for dry and wet climates.

Heat health warning systems continue to evolve to include the addition of a broad range of meteorological and epidemiological predictive data. The Philadelphia, Pennsylvania, Hot Weather Health Watch Warning System (PWWS) (see Fig. 13-4) was developed in part as a result of an historical heat wave in Philadelphia in 1993 and is now becoming the new standard for triggering heat wave response activities. The PWWS uses a temporal synoptic index derived from an algorithm of a complex statistical analysis of historical meteorological and epidemiological data (Kalkstein et al., 1987). An approaching air mass can be evaluated 48 hours in advance of arrival for the potential impact on the health of a metropolitan population. Data from similar historical weather occurrences in the same city at the same time of year are factored in along with the corresponding epidemiological data. The resulting warning provides an estimate of how many heat casualties can be expected based on the history of that city. This type of predictive system is much more rigorous than the heat index. The Director of the NWS, retired U.S. Air Force Brigadier General David Johnson, has stated the PWWS is a model program for the rest of the nation (NOAA, 2005). The proven efficacy of the PWWS has resulted in widespread implementation and continued

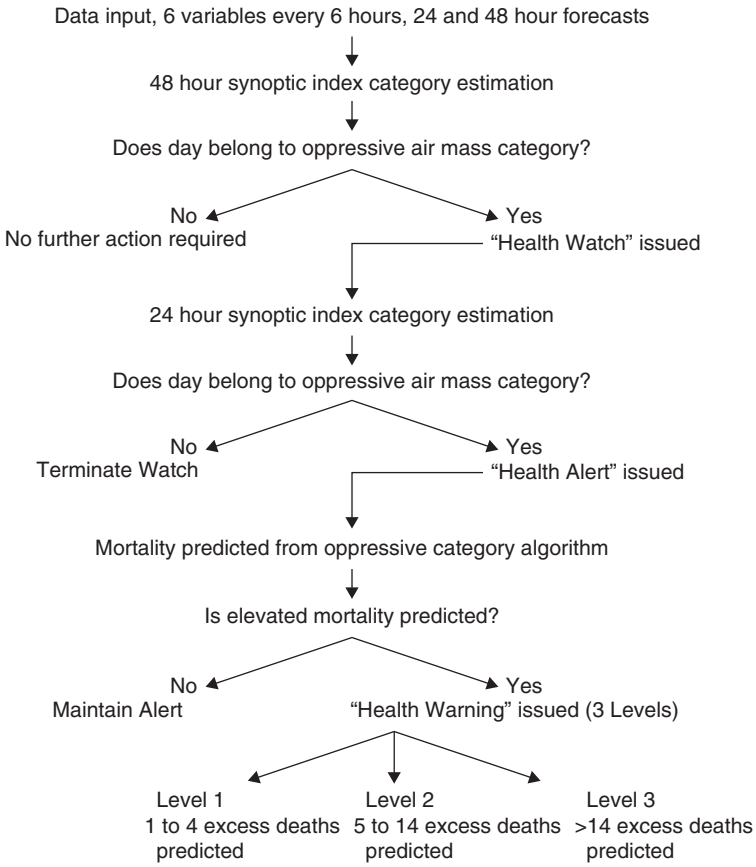


FIGURE 13-4 Configuration of the Philadelphia hot weather health watch/warning system (Kalkstein et al., 1996).

improvements of a heat/health watch warning system by weather service offices serving metro areas throughout the nation. This system is already saving lives by providing more advanced data for enhanced warnings.

Workplace Heat Stress Prevention

Another important risk factor for heat illness or injury is occupational exposure to heat. Jackson and Rosenburg studied a cohort of agricultural workers from 1992 through 2006. The crop worker fatality rate averaged was 20 times higher than the rate for US civilian workers overall. Many of the agricultural workers who died were foreign-born who tend to have limited English language skills and often are not acclimatized to exertion in hot weather when beginning seasonal jobs (Jackson and Rosenberg, 2010). The states of California and Washington have led in adopting workplace safety standards designed to prevent heat-related illnesses. These state regulations include employer provision of drinking water, shade for rest or other sufficient means to recover from heat, worker and supervisor training, and written heat safety plans. There are few reports of indoor workplace related

heat illnesses or deaths outside of the mining industry. The US Occupational Safety and Health Administration (OSHA) does not have a specific standard for heat exposure, but addresses it in several general industry standards and also considers heat exposure to fall under the Occupational Safety Act, Section 5(a)(1), General Duty Clause. This clause simply states that employers must "furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm." In its Technical Manual, OSHA offers guidelines for measuring and assessing heat stress. Most industrial hygiene experts measure heat using wet bulb global temperature (WBGT). WBGT considers other factors in order to estimate the effects of temperature, humidity, wind speed, and visible and infrared radiation (usually sunlight). In establishing the following threshold limit values (Table 13-3), it is assumed, given appropriate loose light clothing and adequate salt and water supplies, workers will be able to function adequately. One of the recent criticisms of these types of guidelines and those established by many occupational authorities internationally, is that the guidelines generally apply to physically fit males and may not be applicable to other workers.

The OSHA guidance (OSHA, 2001) also suggest numerous controls, including:

1. Liberal permission to drink fluids
2. Work rest cycles according to conditions
3. A heat safety program including:
   a. Heat hazards awareness training
   b. Worker risk factor screening program
   c. An acclimation program
   d. Emergency procedures
   e. First aid provision

Those working in hot environments must be trained and informed before regular heat exposure. This includes learning the signs and symptoms of heat stress and appropriate measures to take when they are recognized. A screening process should be in place to identify and quantify worker risk factors. A time must be established for workers' physical acclimatization to hot environments through incremental exposures. The time required to become acclimated will vary from one person to another. Those with certain risk factors

Table 13-3 Permissible Heat Exposure Threshold Limit Values

Work/Rest Regimen	Work Load[a] Light	Moderate	Heavy
Continuous work	30.0°C (86°F)	26.7°C (80°F)	25.0°C (77°F)
75% work, 25% rest, each hour	30.6°C (87°F)	28.0°C (82°F)	25.9°C (78°F)
50% work, 50% rest, each hour	31.4°C (89°F)	29.4°C (85°F)	27.9°C (82°F)
25% work, 75% rest, each hour	32.2°C (90°F)	31.1°C (88°F)	30.0°C (86°F)

[a]Values are in °C and °F, wet bulb globe temperature (WBGT).
OSHA Technical Manual, Section III, Chapter 4.

may never be able to acclimate to extreme conditions. Under ideal conditions, a young healthy individual with no risk factors should be able to fully acclimate to a hot environment in about 2 weeks. This rate of acclimatization requires at least 2 hours of exposure each day combined with gradual increases in cardiovascular exercise. Placing this incremental stress on the body will result in biological adjustments which reduce physiological strain, protect the body, and increase the comfort level. These changes include faster physiological responses to heat, such as earlier and greater sweating and increased blood flow to the skin. However, these changes can be lost at nearly the same rate that they are gained. Workers who do not continue to have periodic heat exposures will experience diminished acclimatization after several days, and may lose about 75% of their acclimatization within about 3 weeks (CHPPM, 2003). Acclimatization will also impact the amount of water required to maintain adequate hydration. An acclimated individual will sweat more quickly and profusely, requiring more fluid intake. The quantity of fluids needed to sustain a healthy and highly active acclimated person may exceed a quart (or liter) per hour.

Case Study: Chicago Heat Wave, 1995

One of the deadliest heat waves in US history occurred in July 1995. The city of Chicago, Illinois, recorded its highest sustained temperatures in decades. A thermal inversion aggravated the situation by trapping pollution close to the ground. The heat was so intense that roads buckled, power failed, and train rails twisted. The heat index during this heat wave set a new record on July 13 at 119°F (48.3°C). The Cook County Medical Examiner's office established criteria for heat-related mortality including:

- core body temperature >105°F (40.6°C) at the time of death
- clear evidence of heat as a contributing factor (eg, discovered in a home without air conditioning)
- victim discovered in decomposed condition with no other apparent causes of death, and evidence that the victim was alive during the heat wave

Identification of heat casualties is a difficult task. During the week of July 4 (July 4–10), none were reported. The period immediately following, July 11–27, 465 heat-related deaths were reported (see Fig. 13-5) (CDC, 1995b). The dramatic increase led to skepticism among local leaders and the media. Mayor Daley was criticized for belated activation of Chicago's "Heat Plan." At the time, the written plan consisted of less than two pages. The mayor quickly blamed utilities for the power outages and accused the medical examiner of exaggerating the heat casualty count. Because primary causes of death are often preexisting conditions among vulnerable populations, determining how much heat conditions contribute to specific deaths is very difficult. The Chicago Medical Examiner used the best available information in tracking heat victims.

Some difficult lessons were learned through this event. Perhaps the most significant lesson is the importance of good communication with the public, emphasizing delivery of warnings and survival tips to those who are poor or elderly. This was clearly a challenge for Chicago. The lack of heat wave preparedness knowledge among local leaders was most apparent in public statements made by the Commissioner of Human Services, Daniel Alvarez. He suggested the victims were to blame when he said, "We are talking about people who died because they

Continued

Case Study: Chicago Heat Wave, 1995—cont'd

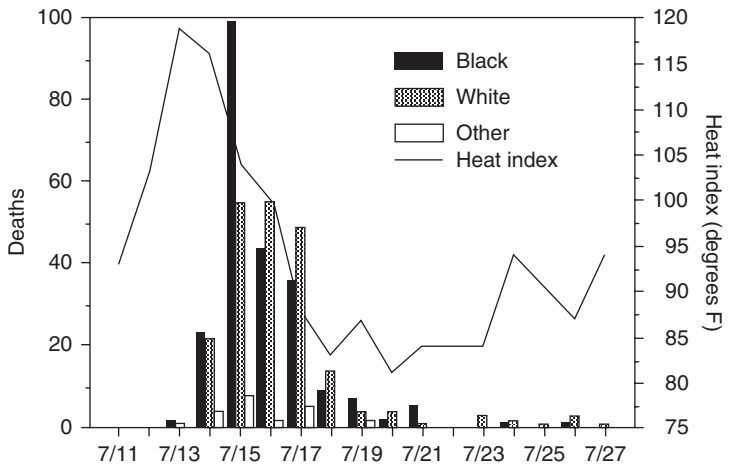


FIGURE 13-5 Number of heat-related deaths, ($n = 465$) by date of occurrence and race (the Cook County Medical Examiner's office categorizes race of decedents as black, white, or other) of decedent, and heat index, by date, Chicago, July 11–27, 1995 (CDC, 1995b).

neglected themselves … people who do not read the newspaper, who do not watch TV. We did everything possible" (Van Biema 1995). He later apologized for those comments. The key take-home message from this incident is that heat wave deaths are preventable, and the key is communication with vulnerable populations before and during the occurrence.

Immediate Actions

The basic steps needed for an effective response to a heat wave begin with community planning and personal preparedness. Vulnerable populations must be identified prior to an emergency. Using the resilient community framework outlined in Chapter 3, Community Disaster Resilience, effective strategies should begin with the formation of a local or regional heat wave task force. Task force members should include representatives from organizations representing vulnerable populations so that specific approaches, unique to each community, can be planned with appropriate triggers for actions such as establishing cooling centers and checking on the elderly. Building a heat wave resilient community includes measures to reduce the possibility of failure or reduction (so-called "brownouts") of critical infrastructures such as power grids. This includes advising the public on basic energy conservation measures during peak hours of heat and energy utility use. Reducing the health impact of heat on vulnerable populations is best achieved by communicating basic personal preparedness measures and emphasizing actions to be taken to cool down and connect with assistance if needed.

Personal Actions

As many of the environmental variables of a heat wave cannot be controlled, those at risk must consider all the personal variables which influence individual risk and plan ahead for the warm season. If a person typically spends time outside in direct sunlight, clothing selection is particularly important. Lighter-colored clothes reflect light and will keep those outdoors much cooler than dark-colored clothing will. Loose-fitting lightweight clothing will allow air to circulate and speed the evaporation of sweat, cooling the body more quickly. Activities should be planned which keep individuals in the shade. If time is spent in direct sunlight, those outdoors should be prepared to wear a hat and use sunscreen with a high sun protection factor (SPF) to reduce the risk of sunburn, which increases all heat illnesses by making it more difficult for the skin to regulate body temperature. Those with risk factors should stay in the coolest place available and avoid strenuous activities in the heat. When engaging in outdoor work or exercise, it is important to avoid excessive exertion during peak temperatures of the day and consider rescheduling more strenuous tasks for cooler times of the day. It is also important to avoid heavy meals. Many foods that are typically considered healthy, such as foods high in protein, are not a good choice during extreme heat. These foods increase the production of metabolic heat and also contribute to water loss. As some medications affect sweat production or blood circulation, it is important to evaluate prescription medications such as blood pressure and psychiatric drugs for their impact on heat stress. Over-the-counter medications such as antihistamines and decongestants can also affect the body's cooling system. The use of illegal drugs, alcohol, and caffeinated products is also a factor that increases the risk of heat-related illness or injury. Those who live alone should be identified and checked on regularly. The majority of heat wave deaths occur among individuals who are alone.

Those with heat injury risk factors must be instructed on simple tactics to reduce the likelihood of experiencing serious heat-related health problems. Individuals without air conditioning, or who lose power during peak hours of heat, should identify nearby air-conditioned safe havens. Accessible air-conditioned areas may include community centers, libraries, and other public buildings. Additionally, shopping malls and other facilities offer cool environments. Important phone numbers of friends and family members, as well as hotline/helpline numbers, should be readily available. A home preparedness plan and kit should be prepared in advance. Before the hot season hits, spaces around window air conditioners should be well insulated. Weather stripping on doors and windows should also be inspected and replaced if needed. Air-conditioning units, ducts, and vents should be inspected annually. Shades, blinds, or drapes can substantially reduce the heat entering a home through direct sunlight, and attic fans can be very effective in reducing heat accumulation in attic spaces.

Community Actions

There is no single plan or program to fit every country or even every region within a country. The central focus of community heat wave preparedness is the identification of and communication with vulnerable populations. The most effective government actions are focused regionally and locally, working through a wide variety of organizations

representing vulnerable populations. Each public and private organization involved must clearly understand its function before the emergency and be prepared to quickly carry out its assigned roles. Nonprofit and faith-based organizations play a central role in reaching out to those at risk. Meal delivery aides, case workers for the elderly and disabled, and bus operators should be educated to watch for signs of heat illness among those they encounter. Much of this effort can be accomplished well in advance of a heat emergency. Extreme heat preparations include these 10 essential steps:

1. Create heat mitigation public education materials.
2. Identify media and public resources to distribute heat wave information to at-risk populations.
3. Identify vulnerable populations in the community for future campaign focus.
4. Identify and prepare potential cooling centers and transportation resources for vulnerable individuals.
5. Coordinate community resources for a heat wave response.
6. Create clinical alerts providing guidance on diagnosis and treatment of heat illness and share them with medical providers.
7. Initiate a heat-related public awareness campaign.
8. Request local agencies serving vulnerable populations contact clients to assess client safety and provide heat preparedness information.
9. Encourage the public to check on high-risk persons who may be affected by the heat.
10. Initiate heat-related death and illness data collection by local public health agencies.

The media can assist in reaching a large portion of at-risk individuals. Local newspapers are often willing to publish a special section with emergency information such as locations of cooling centers and other emergency services. Many more individuals can be reached through school-based initiatives which provide information to children on the importance of checking on those at high risk, including neighbors and family members. The key messages include:

- Stay indoors. Limit exposure to direct sunlight and if air conditioning is not available, stay on the lowest floor of the home out of direct sunlight. If temperatures there are high, go to a local cooling center or public facility with air conditioning.
- Avoid direct sunlight. Sunburn compromises the skin's ability to cool itself. The sun will also raise the internal core temperature leading to dehydration. Use a sunscreen lotion with a high SPF rating if you need to be outside.
- Drink plenty of fluids. The leading cause of heat-related death is dehydration. It can happen quickly and not be noticed until it is too late. The symptoms are frequently confused with other causes. Individuals with existing health conditions or who have problems with fluid retention (individuals with epilepsy, heart, kidney, or liver disease) should consult a doctor before increasing liquid intake.
- Wear light-colored, lightweight, loose-fitting clothing. Cover as much skin as possible with light-colored, loose-fitting clothing to avoid sunburn and overheating effects of sunlight on your body. Light-colored, lightweight, loose-fitting clothing reflects heat and helps maintain normal body temperature.

- Protect the face and head. A hat will keep direct sunlight off your head and face. Sunlight can burn your skin and also increase your core temperature.
- Take frequent breaks. If you are working outside, take frequent breaks in a cool area. Drink noncaffeinated fluids to stay hydrated.
- Avoid strenuous activity during peak hours of heat. Reduce, eliminate, or reschedule strenuous activities. High-risk individuals should stay in cool places during the hottest part of the day. Get plenty of rest to allow your natural "cooling system" to work. If you must do strenuous activity, do it early in the morning or late in the evening during the coolest parts of the day.
- NEVER leave children or pets in vehicles. Temperatures inside vehicles can reach deadly levels within minutes. Exposure to such high temperatures can quickly kill any occupants of the vehicle. Never leave a person or pet in a vehicle for any length of time.
- Limit use of alcohol or caffeinated beverages. These beverages can make you feel better for a brief period of time but increase your vulnerability to heat illnesses.
- Eat light, regular meals. Eat smaller meals more often. Avoid large, heavy meals, as well as food high in protein which generates more internal body heat during digestion. Avoid using excess salt or salt tablets unless directed to do so by a physician.
- Avoid excessive changes in temperature. A cool shower immediately after being in excessive heat may sound refreshing but the drastic temperature shift can result in hypothermia, particularly for vulnerable populations such as the elderly and very young.
- Check on family, friends, and neighbors who do not have air conditioning and/or who spend time alone.
- High-risk individuals should consider spending the peak hours of heat in public buildings such as libraries, schools, shopping malls, and other community facilities.
- High-risk workers should use a buddy system. Partners can keep an eye on each other and assist each other if needed. Sometimes exposure to heat can cloud judgment. Those working alone may not notice this.

Sunset. *CC0 public domain.*

Summary

Heat waves are one of the most lethal and yet subtle disasters. The worst impact is felt among vulnerable populations and many casualties of heat waves die alone. Their deaths are often attributed to other causes or conditions, even though the excessive heat serves as the tipping point for the fatal outcome. Unlike many other disasters where infrastructures experience catastrophic failure resulting in unavoidable fatalities, nearly all heat wave losses are avoidable. The measures taken by those at risk are simple, and the interventions required of local and state government officials are clear. The keys to success are the political will to make heat wave preparedness and response a priority, and effective communication with vulnerable populations. There is historical evidence suggesting that public outcry and political will are essential in gaining the necessary awareness and resources to effectively prepare and respond. The subtle nature of heat waves has proven to be the principal barrier. Global warming and other environmental changes, combined with the growth of urban environments and increasing numbers of susceptible populations, are all contributing factors to the increasing likelihood of future catastrophic heat waves such as those experienced in Chicago in 1995 and Paris in 2003.

Websites

American Red Cross, Heat Wave Safety. http://www.redcross.org/prepare/disaster/heat-wave.

CDC, Extreme Heat and Your Health. http://www.cdc.gov/extremeheat/.

CDC, National Institute for Occupational Safety and Health (NIOSH), Workplace Safety and Health Topics, Heat Stress. http://www.cdc.gov/niosh/topics/heatstress/default.html.

CDC, National Institute for Occupational Safety and Health (NIOSH), Preventing Heat-related Illness or Death of Outdoor Workers. http://www.cdc.gov/niosh/docs/wp-solutions/2013-143/.

Medscape, Heatstroke. http://emedicine.medscape.com/article/166320-overview.

OSHA-NIOSH INFOSHEET: Protecting Workers from Heat Illness. http://www.cdc.gov/niosh/docs/2011-174/.

OSHA Technical Manual: Section III, Chapter 4: Heat Stress. https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html.

San Francisco State University, Department of GeoSciences: Safety Recommendations Fact Sheet: Never Leave Your Child Alone in the Car! http://ggweather.com/heat/fact_sheet_2006.pdf.

U.S. Department of Labor, OSHA Safety and Health Topics: Heat Stress. www.osha.gov/SLTC/heatstress/index.html.

U.S. Environmental Protection Agency, June 2006. Excessive Heat Events Guidebook, Publication EPA 430-B-06-005. http://www.epa.gov/sites/production/files/2014-07/documents/eheguide_final.pdf.

U.S. Environmental Protection Agency, SunWise Program. www.epa.gov/sunwise/.

U.S. Federal Emergency Management Agency, Extreme Heat. http://www.ready.gov/heat.

U.S. National Weather Service. http://www.nws.noaa.gov/om/brochures/heat_wave.shtml.

WebMD, Heat Stroke: Symptoms and Treatment. http://www.webmd.com/a-to-z-guides/heat-stroke-symptoms-and-treatment.

World Health Organization. Heat-health Action Plans Guidance, 2008. http://www.euro.who.int/__data/assets/pdf_file/0006/95919/E91347.pdf.

References

Aerospace Medical Association (ASMA), 2005. Useful Tips for Airline Travel. Retrieved January 19, 2008, from: www.asma.org/pdf/publications/Tips_For_Travelers2001.pdf.

Bernard, S.M., McGeehin, M.A., 2004. Municipal heat wave response plans. Am. J. Public Health 94 (9), 1520–1522.

Centers for Disease Control and Prevention (CDC), 1995a. Heat-related illnesses and deaths—United States, 1994–1995. MMWR 44 (25), 465–468.

Centers for Disease Control and Prevention (CDC), August 11, 1995b. Heat-related mortality—Chicago. MMWR 44 (31), 577–579.

CNN, 2003. Portugal Fires 'Mostly Controlled'. Available at: http://edition.cnn.com/2003/WORLD/europe/08/07/portugal.fires/index.html.

Dhainaut, J., Claessens, Y., Ginsburg, C., Riou, B., 2004. Unprecedented heat-related deaths during the 2003 heat wave in Paris: consequences on emergency departments. Crit. Care 8, 1–2.

Doick, K., Hutchings, T., 2013. Air Temperature Regulation by Urban Trees and Green Infrastructure. UK Forestry Commission.

Hajat, S., Sheridan, S.C., Allen, M.J., Pascal, M., Laaidi, K., Yagouti, A., Bickis, U., Tobias, A., Bourque, D., Armstrong, B.G., Kosatsky, T., June 2010. Heat-health warning systems: a comparison of the predictive capacity of different approaches to identifying dangerously hot days. Am. J. Public Health 100 (6), 1137–1144.

Hemon, D., Jougla, E., 2003. Surmortalité liée à la canicule d'août 2003-Rapport d'étape (Translation: Mortality Related to the Heat wave of August 2003-Report/ratio of stage 1). Retrieved January 13, 2008, from: www.snphar.com/news/stock/caniculeINSERM.pdf.

Jackson, L.L., Rosenberg, H.R., 2010. Preventing heat-related illness among agricultural workers. J. Agromedicine 15 (3), 200–215.

Kalkstein, L.S., Davis, R.E., 1989. Weather and human mortality: an evaluation of demographic and -interregional responses in the United States. Ann. Assoc. Am. Geogr. 79 (1), 44–64.

Kalkstein, L.S., Tan, G., Skindlov, J.A., 1987. An evaluation of three clustering procedures for use in synoptic climatological classification. J. Clim. Appl. Meteor. 26, 717–730.

Kalkstein, L.S., Jamason, P.F., Greene, J.S., Libby, J., Robinson, L., 1996. The Philadelphia hot weather-health watch/warning system: development and application, Summer 1995. Bull. Am. Meteorol. Soc. 77 (7), 1519–1528.

Kizer, K.W., 2000. Lessons learned in public health emergency management: personal reflections. Prehosp. Disaster Med. 15, 209–214.

Mellion, M.B., Shelton, G.L., 1997. Safe exercise in the heat and heat injuries. In: Mellion, M.B., Walsh, W.M., Shelton, G.L. (Eds.), The Team Physician's Handbook, second ed. Hanley & Belfus, Philadelphia, PA, pp. 151–165.

Milwaukee Metropolitan Area, Heat Task Force (MMAHTF), June 2014. Excessive Heat Event Coordination Plan. Available at: http://city.milwaukee.gov/ImageLibrary/Groups/healthAuthors/DCP/PDFs/ExtremeHeat/2014MilwaukeeExcessiveHeatEven.pdf.

Naughton, M.P., Henderson, A., Mirabelli, M.C., et al., 2002. Heat-related mortality during a 1999 heat wave in Chicago. Am. J. Prev. Med. 22, 221–227.

Nicholls, N., Skinner, C., Loughnan, M., Tapper, N., 2008. A simple heat alert system for Melbourne, Australia. Int. J. Biometeorol. 52 (5), 375–384.

Nowak, D.J., Crane, D.E., Stevens, J.C., Ibarra, M., 2002. Brooklyn's Urban Forest. Gen Tech Rep NE-290.

Occupational Safety and Health Administration (OSHA), 2001. Standard Interpretations: 10/17/2001, Acceptable Methods to Reduce Heat Stress Hazards in the Workplace. Available at: www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&;p_id=24008.

Pascal, M., Laaidi, K., Ledrans, M., et al., 2006. France's heat-health watch warning system. Int. J. Biometeorol. 50 (3), 144–153.

Rebetez, M., Mayer, H., Dupont, O., et al., 2006. Heat and drought 2003 in Europe: a climate synthesis. Ann. For. Sci. 63, 569–577.

Sheets, V.L., Manzer, C.D., 1991. Affect, cognition, and urban vegetation: some effects of adding trees along city streets. Environ. Behav. 23, 285–304.

Simon, H.B., 1993. Hyperthermia. N. Engl. J. Med. 329, 483–487.

Tagliabue, J., August 19, 2003. French Official Quits over Toll in Heat Wave. New York Times.

Tan, J., Kalkstein, L.S., Huang, J., Lin, S., Yin, H., Shao, D., 2004. An operational heat/health warning system in Shanghai. Int. J. Biometeorol. 48 (3), 157–162.

United Nations Environment Programme, 2004. Environmental Alert Bulletin: Impacts of Summer 2003 Heat Wave in Europe. Retrieved January 12, 2008 from: www.grid.unep.ch/product/publication/download/ew_heat_wave.en.pdf.

U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM), 2003. Ranger and Airborne School Students Heat Acclimatization Guide. Retrieved January 12, 2008 from: http://chppm-www.apgea.army.mil/doem/pgm34/HIPP/Heat%20-Acclimatization%20Guide_6.pdf.

U.S. Environmental Protection Agency (EPA), 2006. Excessive Heat Events Guidebook, Publication EPA 430-B-06-005, June 2006. Available at: http://www.epa.gov/sites/production/files/2014-07/documents/eheguide_final.pdf.

U.S. Environmental Protection Agency (EPA), 2015. Heat Island Effect. Available at: http://www.epa.gov/hiri/.

U.S. National Oceanic and Atmospheric Administration (NOAA), 1994. National Weather Service Regional Operations Manual Letter. Eastern Region National Weather Service, p. 3.

U.S. National Oceanic and Atmospheric Administration (NOAA), 2005. News Release, NOAA Heat/Health Watch Warning System Improving Forecasts and Warnings for Excessive Heat. NOAA Magazine. Retrieved February 22, 2008, from: www.noaanews.noaa.gov/stories2005/s2366.htm.

Van Biema, D., 1995. More heat than light. Time 31, 37.

Weisskopf, M.G., Anderson, H.A., Foldy, S., et al., 2002. Heat wave morbidity and mortality, Milwaukee, Wis, 1999 vs 1995: an improved response? Am. J. Public Health 92, 830–833.

14

Hurricanes, Typhoons, and Tropical Cyclones

OBJECTIVES

- Explain the difference between hurricanes, typhoons, and tropical cyclones.
- Describe how tropical cyclones develop.
- List the factors that determine storm intensity.
- Describe variables of storm-associated morbidity and mortality.
- Explain how storm surges occur and what influences their severity.
- Describe where the greatest impact of a storm is seen in relation to the eyewall and why.
- List the primary and secondary causes of storm-associated deaths.
- Explain why storm-associated morbidity and mortality have dramatically decreased in recent years.
- Describe what can be done to mitigate the impact of a storm on a home or other structure.
- Besides evacuation, list things an individual can do to reduce the risk of injury during a tropical cyclone.
- Describe the hazards associated with recovery operations.

Introduction: 2005 Hurricane Katrina

Tony was at home in Biloxi, Mississippi, with his two daughters when Hurricane Katrina made landfall. The family lived in a small apartment on the first floor of a two-story building. They huddled in their home as the wind howled that Monday morning. The intensity of the windswept rains steadily grew. Not far away, at the beach, the storm surge started off small, like the tide coming in, but continued to grow. Each wave was slightly larger than the last until the water reached beyond the beach, across the beach highway, and into the city. The murky water surged little by little across Biloxi and grew deeper as the winds swirled and the rain blew. As the flood surrounded buildings, the pulsating rush of water began to weaken and collapse one structure after another.

At their apartment, the growing waves reached the building and ruptured the bottom panel of the front door. They raced to the back bedroom and gathered some of their things. Tony tried to reassure his daughters, 3-year-old Brooke and 8-year-old Shania, that everything would be alright. He tried to hide his own fear as he considered the possibility they may not make it. The little family waded through the rising waters in their

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front room and opened a window. Tony, with a daughter in each arm, climbed out of the apartment into the rising waters and waded to a set of outside stairs leading to the second floor. Although they found refuge above the rising waters on the second floor, Tony could also see buildings around them beginning to collapse. He was faced with a new dilemma—stay where it was safe at the moment or risk trying to get to higher ground. Rather than risking the possibility of their building collapsing, Tony decided to pick up the girls and attempt getting to higher ground. A house just behind their apartment building was likely to be a safer place. With both girls in his arms, Tony swam and waded through water that was now neck deep, swimming between two already damaged buildings to reach a hill behind their apartment building. They knocked on the front door of their neighbor's home, still standing above the rising waters, and were invited in. They rode out the rest of the storm in the safety of their neighbor's home. Although they lost everything in the storm, Tony and his girls came through it alive. After spending some time at a friend's home, Tony and his young family began the arduous process of rebuilding their lives (UNICEF, 2005).

Hurricane Katrina was by far the largest disaster in US history (Fig. 14-1). Even though there have been other hurricanes recorded as more powerful, the timing and location of landfall made Katrina more devastating than any previous storm. The measure of a storm's intensity is based on how low the barometric pressure drops. Barometric pressure is the weight of a column of air from the ground, or water surface, to the top of the atmosphere. It is expressed as inches of mercury (inHg) or millibars (mb). The International System of Units uses hectopascal (hPa), which is equivalent in value to millibars: 1 mb = 1 hPa. Lower pressure means worse weather, whereas high pressure usually means clearer weather. There have only been three US hurricanes more intense than Katrina. In 1935, an unnamed Category 5 hurricane hit the Florida Keys on Labor Day with a barometric pressure of 26.35 inHg and winds of 160 miles per hour (mph) (258 km per hour (kph)). In 1969, Hurricane Camille, also a Category 5 storm, carried a pressure of 26.84 inHg and winds of 190 mph (306 kph). Hurricane Katrina had a pressure reading of 27.17 inHg and winds of 140 mph (225 kph), making it just slightly lower than 1992 Hurricane Andrew at 27.23 (see Table 14-1) (Rice, 2005; NHC, 2011).

Even though Hurricane Andrew had stronger winds at 165 mph compared with Hurricane Katrina's 140 mph (225 kph) winds, Katrina's damage and loss of life were more severe. The statistics of Katrina are staggering. The storm surge directly impacted about 93,000 square miles (240,869 square kilometers), nearly the size of the United Kingdom. The damage was spread across multiple states and over 130 parishes or counties. More than 1330 deaths and the complete destruction of about 300,000 homes are attributed to Hurricane Katrina. More than 1 million people were evacuated, and damage estimates exceeded US$96 billion (Townsend, 2006). Although there have been more intense hurricanes and others with higher death tolls, there has not been another disaster in US history that brought devastation over such a large region or one that has been more cloaked in controversy concerning the overall response.

FIGURE 14-1 Top image, taken in 1998, showing the pier, the pier house, and the antebellum house in Biloxi, Mississippi. The bottom image shows the same location on August 31, 2005, 2 days after Hurricane Katrina made landfall. This photograph shows the complete destruction of these landmarks. *US Geological Survey (USGS) photographs.*

Table 14-1 Most Intense Hurricanes in US History

Hurricane	Year	Landfall Location	Wind Speed (mph/km per hour)	Barometric Pressure (inHg/mb)	Category
Unnamed	1935	Florida Keys	160/258	26.35/892	5
Camille	1969	Mississippi, Louisiana, Virginia	190/306	26.84/909	5
Katrina	2005	Florida, Louisiana, Mississippi, Alabama	140/225	27.17/920	4
Andrew	1992	Florida, Louisiana	165/266	27.23/922	5

National Weather Service (NHC, 2011).

Hurricane and Tropical Cyclone Definitions

Beaufort Scale A 12-point scale developed in the early nineteenth century by Royal Navy Officer Francis Beaufort. It provides a practical measure relating wind speed to observed conditions. On the scale, a measure of 1 is calm and 12 is hurricane force winds. An extended Beaufort Scale has been developed expanding from a 12-point to a 17-point scale to better characterize more-extreme storm conditions.

Center The center generally refers to the vertical axis of a tropical storm defined by the location of minimum wind or minimum pressure.

Cyclone A cyclone is storm circulation in the atmosphere that rotates counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Direct hit This is a close approach of a hurricane or cyclone to a specific location. For locations on the left side of a hurricane or cyclone's track (looking in the direction of motion), a direct hit occurs when the cyclone passes to within a distance equal to the cyclone's radius of maximum wind. For locations on the right side of the track, a direct hit occurs when the cyclone passes to within a distance equal to twice the radius of maximum wind.

Gale warning A warning means that 1-minute sustained surface winds on the water are in the range of 34 knots (39 mph or 63 kph) to 47 knots (54 mph or 87 kph) or wind force of 8 or 9 in the Beaufort Scale. This may or may not be associated with a hurricane or tropical cyclone.

High wind warning A warning means that 1-minute average surface winds on land are 35 knots (40 mph or 64 kph) or greater lasting for 1 hour or longer, or winds gusting to 50 knots (58 mph or 93 kph) or greater regardless of duration that are either expected or observed over land.

Hurricane (typhoon) This is a tropical cyclone with maximum sustained surface wind (using the US 1-minute average) of 64 knots (74 mph or 119 kph) or more. This term is normally used for storms in the Atlantic Basin and the Pacific Ocean east of the International Date Line. The term "typhoon" and "cyclone" are used for Pacific and Indian Ocean tropical cyclones north of the Equator and west of the International Dateline.

Hurricane (typhoon) eyewall The eyewall is a ring of cumulonimbus clouds and thunderstorms that surround the hurricane eye. The heaviest rain and strongest winds are normally found in the eyewall.

Hurricane (typhoon) season This is the time of year with a relatively high incidence of hurricanes or typhoons. The hurricane season in the Atlantic, Caribbean, and Gulf of Mexico is from June 1 to November 30. The hurricane season in the Central Pacific Basin is the same, but the season in the Eastern Pacific and Indian Ocean Basin starts several weeks earlier, from May 15 to November 30. In the South Pacific and Southeast Indian Ocean, the season runs from November 1 to April 30.

Hurricane local statement A release prepared by local US National Weather Service offices that are in or near an area at risk for a hurricane. The statement provides details for each county/parish warning area on weather conditions, evacuation decisions, and other precautions necessary to protect life and property.

Direction of movement The direction toward which the center of the tropical cyclone is moving.

Eye The low-pressure center of a hurricane or cyclone. Winds are normally calm as the eye passes over and sometimes the sky is clear. The eye is surrounded by the eyewall cloud.

Gale force wind Average surface wind speed of 34–47 knots (63–87 kph, 39–54 mph, or wind force of 8 or 9 in the Beaufort Scale).

Indirect hit Generally refers to an area near landfall not experiencing a direct hit from a hurricane or cyclone but experiencing high winds (sustained or gusts) and/or tides of at least 4 ft (1.2 m) above normal.

Landfall The location of intersection of the center of the storm with a coastline.

Major hurricane A hurricane classified as Category 3 or higher.

Radius of maximum winds The distance from the center of a hurricane or cyclone to the location of the cyclone's maximum winds. In a well-developed hurricane, the radius of maximum winds is generally at the inner edge of the eyewall.

Storm force wind Average surface wind of 48–63 knots (88–117 kph, 55–73 mph, or Beaufort force 10 or 11).

Storm warning A warning means sustained winds of 64 knots (74 mph) or higher associated with a storm are expected in a specified coastal area in 24 hours or less. A hurricane warning can remain in effect when dangerously high water or a combination of dangerously high water and exceptionally high waves continues, even though winds may be less than hurricane force. If told to move to a shelter or evacuate the area, do so immediately.

Storm watch A storm watch means a storm is possible in the watch area, generally within 36 hours. Individuals should continue to listen to US National Oceanic and Atmospheric Administration (NOAA) weather radio, local radio, or local television for updated information. Storms can change direction and speed and can gain strength quickly. It is important to be aware of updated information several times a day.

Storm surge The difference between the actual sea level under the influence of a meteorological disturbance (storm tide) and the normal astronomical tide caused by an abnormal rise in the sea level accompanying a hurricane or other intense storm. It is estimated by subtracting the normal or astronomic high tide from the observed storm tide.

Storm tide The actual level of sea water resulting from the astronomic tide plus the storm surge.

Tropical cyclone A nonfrontal low-pressure system of synoptic scale developing over warm waters and having a definite organized wind circulation with a maximum 10-minute average wind speed of 34 knots (63 kph, 39 mph, i.e., gale force) or greater near the center. Also be referred to as a hurricane or typhoon.

Tropical depression A synoptic low-pressure area with closed wind circulation around a center with wind speeds (using the US 1-minute average) of 20–33 knots (38 mph or 62 km/hour) or Beaufort force 7.

Tropical storm Maximum sustained surface wind speed (using the US 1-minute average) ranges from 34 knots (39 mph or 63 km/hour) to 63 knots (73 mph or 118 km/hour). The storm is named once it reaches this tropical storm strength.

Tropical storm warning A warning that a storm with sustained winds of 34–63 knots (39–73 mph or 63–118 km/hour) is expected to make landfall in a specified coastal area within 24 hours or less.

Tropical storm watch An announcement for a specific coastal area that a tropical storm is possible within 36 hours.

Typhoon This is a tropical cyclone or hurricane in the western Pacific area or China seas.

Hurricanes, Typhoons, and Tropical Cyclones

Hurricanes, typhoons, and tropical cyclones are severe tropical storms. Although these storms share common characteristics in formation and impact, the term used is determined by wind speed and location (see Table 14-2), For example, once a tropical cyclone

Table 14-2 International Storm Designations and Wind Speeds

Region	<17 knots (kt) <32 km per hour (kph) <20 miles per hour (mph)	17–28 kt 32–52 kph 20–32 mph	28–34 kt 52–63 kph 32–39 mph	34–48 kt 63–89 kph 39–55 mph	48–64 kt 89–119 kph 55–74 mph	64–90 kt 119–167 kph 74–104 mph	90–116 kt 167–215 kph 104–134 mph	116–120 kt 215–222 kph 134–138 mph
1	Low-pressure area	Tropical depression		Tropical storm	Severe tropical storm	Typhoon		
2	Tropical disturbance	Tropical depression		Tropical storm		Hurricane		
3	Low-pressure area	Depression	Deep depression	Cyclonic storm	Severe cyclonic storm	Very severe cyclonic storm		Super cyclonic storm
4	Tropical disturbance	Tropical depression		Moderate tropical storm	Severe tropical storm	Tropical cyclone	Intense tropical cyclone	Very intense tropical cyclone
5	Tropical disturbance	Tropical depression		Tropical cyclone		Severe tropical cyclone		

1, Western North Pacific Ocean and South China Sea; 2, Atlantic and Northeast Pacific Oceans including the Caribbean and Gulf of Mexico; 3, North Indian Ocean including Bay of Bengal and Arabian Sea; 4, Southwest Indian Ocean; 5, South Pacific Ocean and Southeast Indian Ocean.
Adapted from Burroughs (2003).

reaches winds of 64 knots (kt) (119 km per hour (kph) or 74 miles per hour (mph)), it is referred to as a:

1. "Typhoon" in Western North Pacific Ocean and South China Sea
2. "Hurricane" in the Atlantic and Northeast Pacific Oceans including the Caribbean and Gulf of Mexico
3. "Very severe cyclonic storm" in the North Indian Ocean (Bay of Bengal and Arabian Sea)
4. "Tropical cyclone" in the Southwest Indian Ocean
5. "Severe tropical cyclone" in the South Pacific Ocean and Southeast Indian Ocean

These storms form over warm water and draw energy from the evaporation of water as they pass over the ocean surface. The storms begin simply as an area of low pressure and thunderstorms called a tropical disturbance. As the warm air causes water to evaporate, it creates lift in the low-pressure area. The rising warm, moist air releases energy as it cools and condenses into rain clouds. The process continues building energy in the rainclouds which can erupt into a violent storm encompassing hundreds of square miles. As the winds begin to rotate over the warm water, energy continues to build, eventually creating a hurricane, typhoon, or tropical cyclone. Throughout this chapter, the term "hurricane" will be used.

It was not until the 1970s that hurricanes in the Atlantic and Northeast Pacific Oceans were ranked, based on intensity, into Categories 1 through 5. An engineer in Florida, Herbert Saffir, worked with the director of the US National Hurricane Center, Robert Simpson, to develop a scale that is now referred to as the Saffir–Simpson Hurricane Scale (Table 14-3). This simple rating is used to estimate the anticipated damages and threats to coastal residents posed by a hurricane. There are geographical differences in each coastal region that have a strong influence on the interpretation of this ranking. A lower-ranked storm can produce more damage in one area than can a higher-ranked storm in another area depending on where it makes landfall. Actual damage is dependent on locations, infrastructure vulnerabilities, and population characteristics of where the storm makes landfall. Additionally, side effects, such as storm surge, are not accounted for in this system and these elements may have significant impact, sometimes more than the direct storm damage. The Saffir–Simpson model uses a 1-minute measurement period, at 10 m (33 ft) above the surface. There are a variety of similar measures used in other regions. For example, the scale used in New Delhi, India, by the Regional Specialized Meteorological Center has a 3-minute measurement period, while the Australian scale uses two measurements, 3-second wind gusts and maximum sustained winds in a 10-minute interval (WMO, 2008, 2010). Each of these measurements has proved to be useful in the regions in which they are applied. However, these methodological variations make it difficult to compare storms in different regions of the world.

Before there were quantitative measures, such as wind speed, to characterize storms, a qualitative measure was developed in the nineteenth century called the Beaufort Scale (Table 14-4). This scale is used to measure wind speed based on observations rather than specific measures. Developed in 1806 by English Admiral Sir Francis Beaufort (1774–1857), it originally ranged from strength 0 (calm) to force 12 (hurricane). Beaufort measures up to force 17 were added to characterize more extreme storms. The original scale was formally adopted

Table 14-3 The Saffir–Simpson Hurricane Scale

	1	2	3	4	5
Category	**Minimal**	**Moderate**	**Extensive**	**Extreme**	**Catastrophic**
Winds	74–95 mph 64–82 knots 119–153 km/hour	96–110 mph 83–95 knots 154–177 km/hour	111–130 mph 96–113 knots 178–209 km/hour	131–155 mph 114–135 knots 210–249 km/hour	>155 mph >135 knots >249 km/hour
Storm surge	4–5 ft	6–8 ft	9–12 ft	13–18 ft	>18 ft
Pressure	>980 mb >28.94 in.	965–979 mb 28.50–28.91 in.	945–964 mb 27.91–28.47 in.	920–944 mb 27.17–27.88 in.	<920 mb <27.17 in.
Anticipated wind damage	No significant damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs.	Some roofing material, door, and window damage. Considerable damage to shrubbery and trees. Considerable damage to mobile homes, poorly constructed signs, and piers.	Some structural damage to small residences and utility buildings with a minor amount of curtain wall (building facade) failures. Damage to shrubbery and trees, with foliage blown off trees and large trees blown down. Mobile homes and poorly constructed signs destroyed.	More extensive curtain wall (building facade) failures with some complete roof failures on small residences. Shrubs, trees, and signs blown down. Complete destruction of mobile homes. Extensive damage to doors and windows.	Complete roof failure on many buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs down. Complete destruction of mobile homes. Severe and extensive window and door damage.
Anticipated storm surge damage	Some coastal road flooding and minor pier damage.	Coastal and low-lying escape routes flood 2–4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings.	Low-lying escape routes may be cut off by rising water 3–5 hours before hurricane center arrival. Flooding near coast destroys small structures. Large structures damaged by battering from floating debris. Terrain lower than 5 ft above mean sea level may be flooded inland 8 miles (13 km) or more. Evacuation of low-lying residences within blocks of the shoreline may be required.	Low-lying escape routes may be cut by rising water 3–5 hours before arrival of the center of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 ft above sea level may be flooded requiring massive evacuation of residential areas as far inland as 6 miles (10 km).	Low-lying escape routes cut off by rising water 3–5 hours before hurricane center arrival. Major damage to lower floors of all structures less than 15 ft above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5–10 miles (8–16 km) of the shoreline may be required.

Adapted from the National Weather Service, National Hurricane Center. Description of the Saffir–Simpson Hurricane Scale. Available at: http://www.nhc.noaa.gov/aboutsshs.shtml.

Table 14-4 The Beaufort Scale

Beaufort Scale Measure	Description	Average Wind Speed at 10 m High in an Open Area		Observed Effects on Land and Sea
		mph	kph	
0	Calm	<1	<1	Smoke rises vertically; sea like glass
1	Light air	1–3	1–5	Wind direction indicated by the train of smoke; small ripples in the water
2	Light breeze	4–7	6–11	Wind felt on face, leaves rustle; small wavelets that do not crest
3	Gentle breeze	8–12	12–19	Wind moves thin branches and stretches flags or pennants; small crests begin to break in water
4	Moderate breeze	13–17	20–28	Wind moves twigs and smaller branches, raises dust and loose paper; larger waves form with frequent crests
5	Fresh breeze	18–24	29–38	Small trees start to sway, moderate sized branches of larger trees move; moderate waves with white crests and some spray
6	Strong wind	25–30	39–49	Large branches moving, umbrellas are difficult to use, overhead wires whistling in the wind; large waves begin to form
7	Stiff wind, near gale	31–38	50–61	Whole trees in motion. Effort needed to walk against the wind. Swaying of skyscrapers may be felt, especially by people on upper floors; moderately high waves
8	Gale force, stormy wind	39–46	62–74	Branches break from trees, makes it extremely difficult to walk outdoors; moderately high waves
9	Gale, storm	47–54	75–88	Branches break from trees, minor damage to houses (tile or smoke hoods lifted); high waves with visible spray
10	Severe gale or storm	55–63	89–102	Wind breaks trees, greater damage to homes; very high waves with large crests
11	Violent, gale force storm	64–73	103–117	Wind uproots trees, widespread storm damage; exceptionally high waves at sea
12	Hurricane	>74	>118	Considerable widespread damage; air near water filled with foam and spray

Adapted from German Meteorological Service, Beaufort Scale (Deutscher Wetterdienst, Beaufort-Skala). Available at: http://www.deutscher-wetterdienst.de/lexikon/index.htm?ID=B&DAT=Beaufort-Skala.

for international maritime navigation in 1874 and revised several times since (Stewart, 2005). The Beaufort Scale is still commonly used in several nations, including China and Taiwan.

The naming of tropical storms was started years ago to make it easier to identify and associate warnings with specific storms (Figs. 14-2 and 14-3). This was an arbitrary

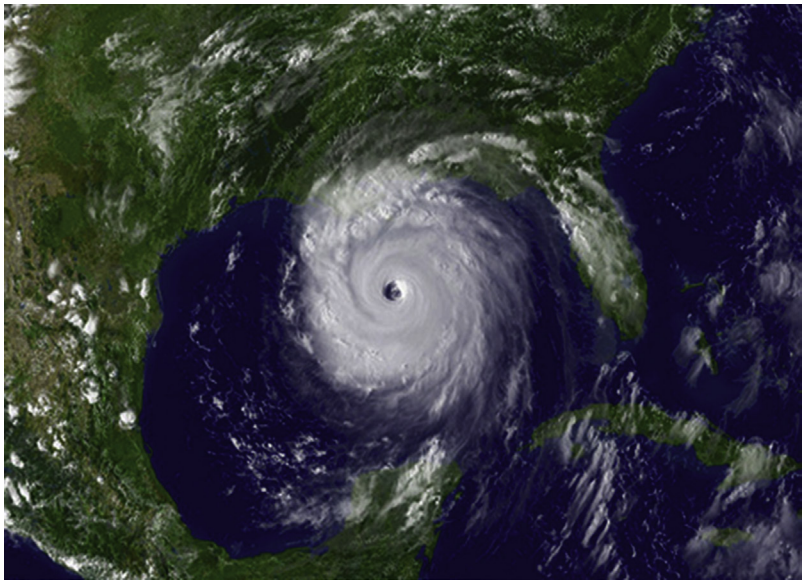

FIGURE 14-2 Hurricane Katrina in the Gulf of Mexico on August 28, 2005. *Photograph from U.S. National Oceanic and Atmospheric Administration (NOAA) .*

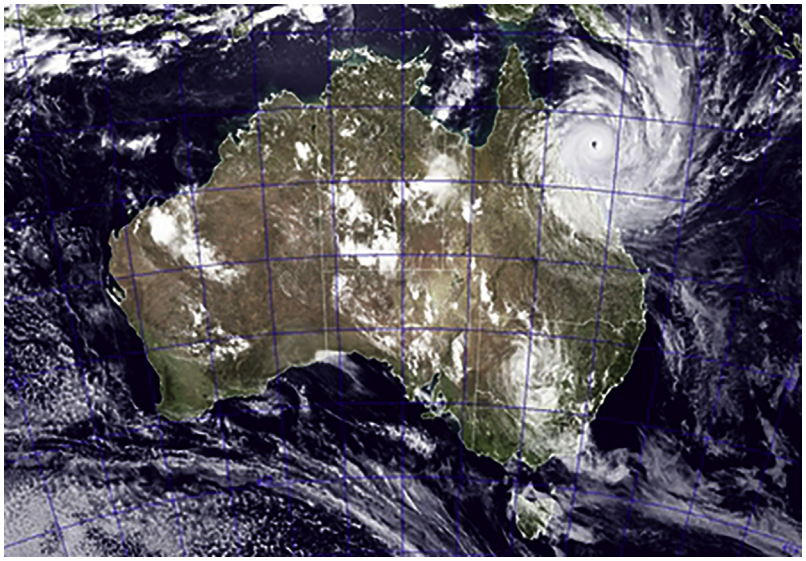

FIGURE 14-3 Tropical Cyclone Yasi as it approaches Queensland, Australia, on February 2, 2011. *Photograph from the US National Aeronautics and Space Administration (NASA).*

practice that started in the early twentieth century. Originally, storms were named by when or where they hit (e.g., Galveston Hurricane, Labor Day Hurricane). However, during World War II, military meteorologists needed to be able to quickly communicate the status of multiple storms that could impact military missions throughout the Pacific, so the naming of storms began. After the war, the meteorology community saw the benefits of storm naming and adopted it as a formal process. In 1953, the US National Hurricane Center developed a list of female names used to label tropical storms in the Atlantic. In 1979, alternating male names were added. Over the years, the practice of storm naming was extended to every region of the world, and the lists for the next 6 years are maintained by the World Meteorology Organization. Once a list of names is used, it is retired for 6 years and then reused. The exceptions to this process are the names of storms that become major hurricanes; those names are replaced. For example, the name "Katrina" is retired and will not be used for another storm, but other storm names from 2005 were used again in 2011. Each year, the alphabetized list denotes the order of the arriving storms. The first tropical storm of the season is a name beginning with the letter "A," the second with the letter "B," and so on. The lists of names are recognizable for those at risk. For example, the 2016 North Atlantic storms that threaten the United States will include 21 names beginning with Alex, Bonnie, Colin, and Danielle. Twenty-one letters of the alphabet are used; five of them (Q, U, X, Y, and Z) are not used. In other regions of the world, the names are selected from a list of names contributed by each nation at risk in the region. For example, in the Northern Pacific and South China Sea region, the names on an upcoming list include Damrey (Cambodia), Haikui (China), Kirogi (DPR Korea), etc. (WMO, 2015).

The hazards associated with hurricanes are unique to each storm. Although associated hazards consistently include storm surge, flooding, high winds, and tornadoes, the predominant hazard for a given hurricane is not always predictable. This unpredictable nature is most apparent in the morbidity and mortality recorded for each storm. Though one storm may have deaths primarily attributed to drowning, another may have few drowning deaths and a large number of traumatic injuries due to high winds. Other storms have varying balances of both.

Because most storms impact coastal areas, a primary factor in the loss of life from most hurricanes is the storm surge. Simply put, storm surge is water pushed ashore by the winds of a hurricane. Storm surge is worst near the eye of the storm and the size of the eye influences the amount of the storm surge as much as the severity of the storm. A "tighter" eye in a more severe storm can have less storm surge than a larger eye in a less severe storm. For example, a dome of water ranging from several feet to as high as 25 ft (nearly 8 m) builds and is pushed ashore as the hurricane makes landfall. The severity can be influenced by a number of factors. The intensity and speed of the storm determine the size of the water dome. The slope of the sea floor and the angle in which the storm hits the shoreline influence how much of the dome is carried ashore. In the Northern Atlantic, the storm rotates counterclockwise, making the right front quadrant of the storm at landfall the area with the greatest surge. The areas left of the eye at landfall have winds blowing toward the ocean, reducing the storm surge. In addition, if the sea floor has a gradual slope, the surge is likely to be far more severe than in areas where the sea floor has a shelf that can help block the surge. The astronomical

tide is also an important factor. If the hurricane makes landfall during high tide, the storm tide will be that much deeper (Fig. 14-4). Because water weighs about 1700 pounds per cubic yard (1009 kg/m^3), the rush of a storm surge is capable of leveling nearly any structure (NHC, 2015). Only specially designed buildings can withstand a major storm surge.

As storm predictions have improved, the drowning deaths from hurricane storm surges have dropped dramatically. However, a closely related hazard continues to take lives further inland during and after the landfall. The intense rainfall from a hurricane or tropical storm is a significant threat to areas farther away from the shoreline. Although weaker, slow-moving storms can have less of a storm surge and spare the coastal areas, these storms can stall even hundreds of miles inland and pour a massive amount of rain resulting in widespread flooding. In recent history, flooding has become the primary cause of US hurricane-related fatalities.

The deadliest tropical cyclone in recorded history is the 1970 Great Bhola Cyclone. Although this cyclone did not reach the strength of a Category 5 hurricane, it inflicted many more fatalities than any previous single weather event. This devastating cyclone developed in the Bay of Bengal and made landfall at night in Bangladesh during a high tide with winds reaching 140 mph (225.3 km/hour). The region is densely populated with many living in poorly constructed homes less than 20 ft (6 m) above sea level. Making matters worse, there was no warning system for those living in the region and the storm hit while most were sleeping. Fatality estimates range from 300,000 to 500,000 (Longshore, 1998; Emanuel, 2005). In comparison, Hurricane Katrina was responsible for over 1300 fatalities in 2005, less than 1% of the Great Bhola Cyclone.

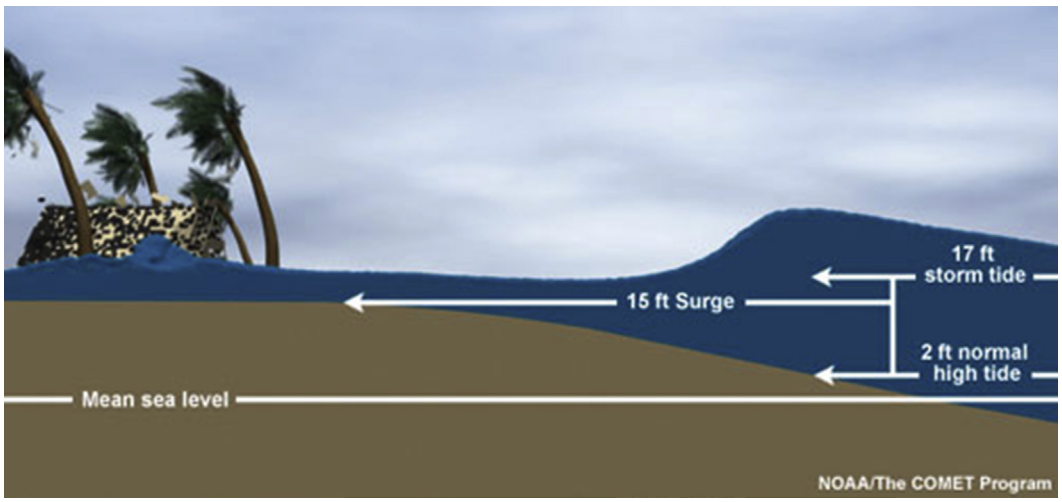

FIGURE 14-4 A storm tide is the combination of an abnormal rise of water due to a storm combined with normal tides and conditions. For example, if the normal tide is 2 ft (0.6 m) and a storm surge is 15 ft (4.6 m), the total storm tide will be 17 ft (5.2 m). The timing of this tide and storm surge has major implications for morbidity, mortality, and response activities. *Image from U.S. National Oceanic and Atmospheric Administration (NOAA).*

Wind speed is the primary quantitative measure used to characterize hurricane, cyclone, or typhoon severity. The risks associated with storm force winds include the destruction of residences, or the blowing out of windows, especially in high-rise structures. Falling trees are often responsible for fatalities and property damage. Power lines can be damaged, posing electrocution hazards and cutting off vital utilities.

In addition to the high winds, some storms also produce tornadoes. Although tornadoes are most likely to occur in the right front quadrant of a north Atlantic hurricane, they can be found anyplace in the rain bands. These tornadoes are different than those occurring with noncyclonic storms as they are typically smaller and do not have the associated lightning and hail seen with other tornadoes. Although they are more likely during the day, hurricane related tornadoes can occur at any time for several days following landfall. Though some hurricanes will produce no tornadoes, some produce many. In 1967, Hurricane Beulah is believed to have generated 141 tornadoes (NHC, 2015). These added weather events complicate an already difficult disaster response.

Human Health Effects

Unlike other types of disasters, the causes of morbidity and mortality related to tropical cyclones are not consistent or predictable. Though some tropical cyclones cause more injury and loss of life from trauma due to high winds and building collapse, others have few injuries related to wind but have large numbers of drowning victims (Fig. 14-5). Accurately accounting for storm-related morbidity and mortality is difficult. In mass fatality situations, autopsy services and detailed record keeping may not be available or may not

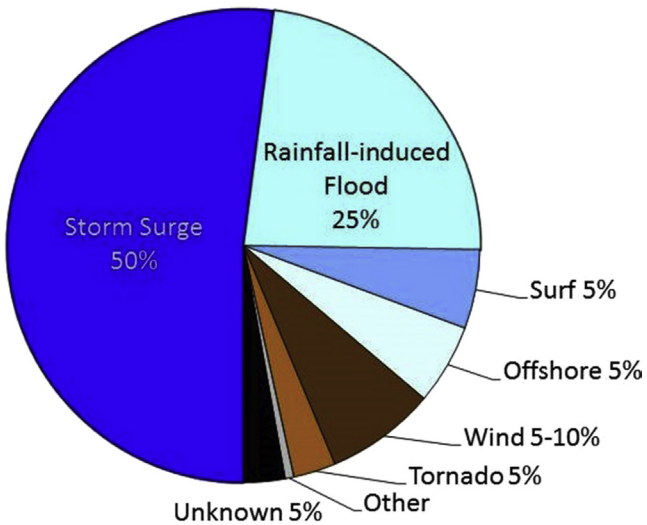

FIGURE 14-5 US Atlantic tropical cyclone deaths, 1963–2012. *Image from the US National Weather Service, National Hurricane Center.*

be a priority in resource-depleted areas. Death certificates have limitations on the quantity and quality of information recorded, and many systems do not have the ability to detail the cause of injuries or death. Postdisaster mortality epidemiology is frequently deferred to prioritize rescue and recovery efforts. However, morbidity and mortality information is important to learn from each disaster and to understand what may be improved to limit future loss of life. For example, the estimated hour of death can be an important piece of information. If a person is lost due to a structural collapse from high winds, there may be an engineering or building code issue that should be considered as a future mitigation measure. If the time of death is several hours later, when winds have slowed, there may be a problem with response or communication of postdisaster risks. While morbidity and mortality data may be inconsistent from one storm to another, they still provide useful information for future preparedness and mitigation activities.

In 1992, Hurricane Andrew made landfall in Florida. One of only three Category 5 storms to hit the United States in recorded history, Hurricane Andrew caused massive damage and killed 44 people. These deaths all occurred in only two of the 11 local counties most affected. Of the 44 deaths recorded in Florida, 15 (34%) were directly related to the hurricane and 29 (66%) were indirectly related. Among those who died as a direct result of the storm, only two were drowning victims. The other 13 (87%) were trauma and asphyxiation victims from collapsing structures. The 29 indirect deaths included 16 naturally occurring premature deaths. Twelve of those premature deaths were stress-induced cardiovascular events. Eight deaths were due to blunt trauma resulting from accidents and falls. The remaining five indirect fatalities were from miscellaneous causes such as a fire, electrocution, lightning strike, and asphyxiation (Combs et al., 1996). There are no consistent trends for morbidity and mortality related to Hurricane Andrew aside from a trend toward trauma-related deaths and few drowning deaths.

Seven years later, another hurricane hit the East Coast of the United States. This time landfall was in North Carolina. Hurricane Floyd made landfall as a Category 3 storm, although it covered a much larger area than most Category 3 storms. Despite the Category 3 ranking, this storm killed more people than the Category 5 Hurricane Andrew. Hurricane Floyd took 52 lives. Drowning was the leading cause of death and took 36 lives (69%). The second leading cause of death was motor vehicle accidents, which killed 7 (13%) people excluding those who drowned in vehicles lost in floodwaters (CDC, 2000). The deaths attributed to Hurricane Floyd were 69% drowning victims compared with less than 5% drowning victim fatalities with Hurricane Andrew (compare Figs. 14-6 and 14-7). The characteristics of the storm, topography of the landfall region, local infrastructure, and behavior of those at risk are the primary storm-related morbidity and mortality factors.

Although the United States has seen a dramatic reduction in the number of fatalities due to hurricane storm surge, it remains the primary risk in other parts of the world. With continued population growth along coastal areas in developing countries, such as Bangladesh with insufficient infrastructure and difficulties conducting evacuations, storm surges will continue to be a leading cause of death (Chowdhury et al., 1992; Diacon, 1992).

FIGURE 14-6 Hurricane Andrew destruction in Dade County, Florida, August 24, 1992. *Photograph by Bob Epstein, Federal Emergency Management Agency (FEMA).*

FIGURE 14-7 Hurricane Floyd inland flooding across much of eastern North Carolina. *Photograph by J. Jordan, US Army Corps of Engineers.*

The top three hurricane- or typhoon-related, nondrowning injuries are blunt trauma, lacerations, and puncture wounds. As mentioned, affected infrastructure and individual behaviors influence injury characteristics. About 80% of hurricane-related injuries are typically to the feet and lower extremities (Noji, 1993). However, a retrospective review of injuries found that in tropical cyclone–related injuries in Hong Kong, the head and upper

limbs are the most commonly affected sites. Falls and being hit by falling or flying objects were cited as the most common mechanisms of injury. In this review, hourly maximum gust appeared to be more important than mean hourly wind speed in determining risk of injury (Rotheray et al., 2012).

There are also infectious disease concerns following these storms. As critical utilities, such as water, sewer, and electricity, as well as public health infrastructure are affected, the risk of disease outbreaks increases. This risk is further aggravated by the displacement and sheltering of populations (UNDP, 2012; Western, 1982). Outbreaks associated with tropical cyclonic storms are rare in developed nations and usually limited to minor noncommunicable gastrointestinal or respiratory illnesses (CDC, 1993, 2000; Toole, 1997). However in developing countries or rural areas, damage to already underresourced infrastructure may have significant environmental health outcomes. Deng et al. (2015) found that bacillary dysentery risk is greatest on days 5–6 after the storm and that rainfall was the greatest factor. Daily precipitation of greater than 25 mm (1 in.) per day was found to be a significant threshold for disease outbreak. The take-away message is these storms make the spread of existing infectious diseases easier because of the compromised infrastructure and living conditions. It is rare that any new disease is introduced.

Prevention and Preparedness

There are many things governments and individuals can do to reduce the morbidity and mortality associated with hurricanes or typhoons. The most important challenge is public awareness and warnings. In the United States and many other countries, coastal regions are becoming more populated with residents and visitors. This swell in population increases the health and safety risks associated with storm surge. Advances in storm forecasting have reduced the populations at risk through evacuations; however, the growing number of residents who choose to live along the coast continues to make evacuation more challenging. Transient populations to these areas also may not be aware of evacuation information or how to follow warnings and instructions. If the community is not expected to be able to fully evacuate, then shelters should be planned. Vertical sheltering in areas subject to storm surge is preferable. A vertical shelter is a hardened, elevated structure or reinforced upper floor. In resource-poor regions, these vertical shelters may be designed for multiple uses even when not used for storm response. Sheltering of animals must also be part of any community's plans whether planning for sheltering of companion animals or farm animals (Narupama, 2013).

There is an important distinction between the generic use of the term "shelter" and a shelter or a safe room meeting formal criteria approved by engineering professionals. Some buildings are designed to provide protection against natural hazards, such as hurricane force winds, while others offer little protection. Taking shelter in a building that appears sturdy does not constitute an approved or effective shelter. Many buildings cannot withstand high winds. However, those that do not provide adequate protection can be fitted with an internal safe room. In the United States, specific design criteria for shelters and safe rooms have been developed and promoted through the Federal Emergency Management Agency (FEMA) (FEMA, 2010, 2011a, 2014).

Local communities can mitigate the impact of hurricanes through the enforcement of building codes developed to strengthen roofing, water barriers, and roof-to-wall connections of buildings. The roof should be reinforced with straps or additional clips to secure the roof to the frame. Simple measures such as adding addition bracing to the gable ends of the roof can prevent collapse during high winds (Fig. 14-8). The gable end is one of the weak points of most structures. When high winds hit the side of a home, roof collapse often begins with the collapse of the gable (side wall in the attic) (FEMA, 2011b). Details on roof gable bracing and other mitigation approaches are available through local emergency planners and online through the FEMA.

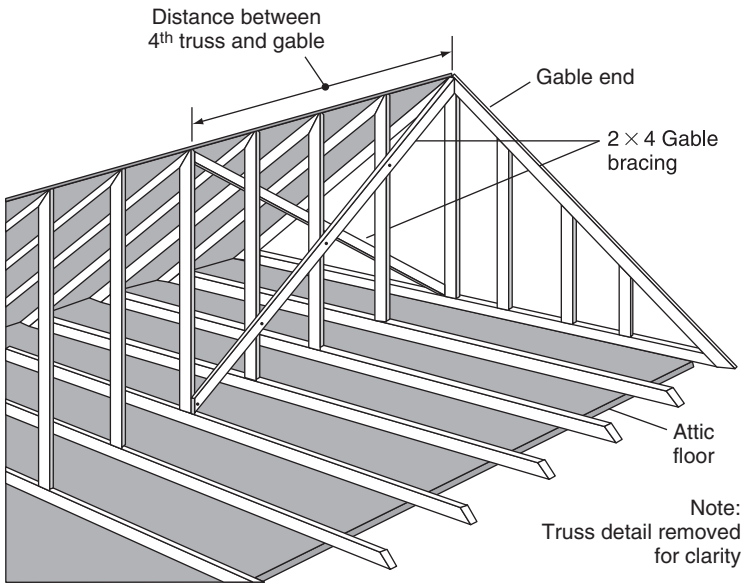

FIGURE 14-8 Additional bracing added to the gable end of a roof to resist the wind. The X-shaped gable bracing can reduce the likelihood of high winds compromising the gable end of the roof during a storm. *Image from FEMA.*

Windows are another weak point of a structure. Although permanent storm shutters offer the best window protection, 5/8-inch (16-mm) marine plywood can also be cut to fit and installed. Windows are likely to be blown out during high winds, and a barrier is needed to prevent blowing rain from flooding the inside of the structure as well as to prevent damage or injury from breaking glass. Taping the windows offers little protection. Double entry doors are another potential point of weakness that should be reinforced with additional hardware. It is also important to bring in yard ornaments and furniture and to trim trees or large shrubs. During a storm, trees can collapse, and loose items in the yard, as well as tree branches, can become damaging "missiles." Simple measures such as cleaning out the gutters and downspouts can reduce the risk of water intrusion.

Population expansion and community development continue to encroach on the natural barriers that can protect from hurricane and typhoon damage. Restoration of coastal

and estuarine habitats such as marshes, wetlands, oyster reefs, and tidal streams is an important step toward making at risk populations safer from the impact of storms (NOS, 2015). The US National Ocean Service is engaged in a variety of initiatives restoring natural resources by providing tools and materials to enhance the habitats that provide natural barriers to hurricanes and other threats.

Top 10 Tropical Cyclone Hazard Mitigation Actions

1. Trim trees and remove other potential windborne missiles.
2. Cover windows with plywood storm shutters.
3. Reinforce roof anchoring to the frame of the structure.
4. Brace the gable end of roof framing.
5. Secure metal siding and metal roofing.
6. Reinforce double entry doors and garage doors.
7. Install sewage backflow valves.
8. Build with or retrofit with flood-proof materials.
9. Flood-proof utilities such as private wells, electrical equipment, and heating/air conditioning equipment.
10. Maintain a family preparedness plan, evacuation plan, and emergency supply kit.

Immediate Actions

When a tropical cyclone is forecasted, those in the path should follow the instructions of local authorities. Factors influencing compliance with evacuation instructions are complex and include access and ability to understand the instructions (literacy, language, signage), the ability to carry out the directions (access to transportation, knowledge of roads), and understanding the risks and benefits of evacuation (Fig. 14-9). Authorities planning for evacuations can use modeling techniques and drills to determine how their community may best address these factors. For example, using models and observing how a community and subcommunities will react to evacuation information can determine best pathways, best messaging, time-frames needed to evacuate, and acceptance of instructions (Duanmu et al., 2011; Langan and Palmer, 2012). Some coastal communities in the United States issue evacuation orders up to 24–36 hours before landfall to allow for a safe evacuation and to prevent having anyone caught on the roads during the landfall of the early storm bands. However, it is not uncommon for elected officials and some residents to delay evacuation until the storm's landfall in their community appears imminent. While this delay may reduce the social and economic costs of unnecessary evacuation, it may also place individuals and communities at risk.

Messaging must be competent for cultural and risk acceptance factors. If a community or individuals do not believe messages, they will not follow the recommendations. Past

FIGURE 14-9 Hurricane evacuation sign. *Image from the Centers for Disease Control and Prevention (CDC).*

experiences with authorities can influence the messages' public acceptance (Harro-Loit et al., 2012). Those who cannot evacuate should be instructed to seek refuge in a sturdy shelter on high ground. This is particularly true for individuals living in mobile homes or temporary structures, but it also applies to those in high-rise buildings. If wind is a predominant factor of the storm, the winds are stronger at higher levels. Individuals in multistory buildings should evacuate to lower floors. Those living or working in low-lying areas along the coast, near inland waterways, or near rivers and streams should be prepared to quickly evacuate to higher ground to avoid the storm surge. Utilities, including gas and electricity, should be turned off when warnings are issued for an impending evacuation.

If there are no designated shelters available and affected structures do not have safe rooms, individuals should be instructed to stay indoors and away from windows. Blinds and curtains should be closed to deflect glass if a window is blown out. All doors should be closed and external doors should be braced. Shelter may be taken in a small inner room or space such as a bathroom, closet, or hallway. A sturdy piece of furniture may also be used to provide additional protection. Many survivors of major storms have had to change their sheltering plans during a storm due to flooding or risk of structural failure, as illustrated by this chapter's introductory case example. Plans must always include identifying the next nearby safe location in which to evacuate in the event the original shelter location is compromised. Warnings should also include awareness of the calm "eye" of the storm. If the winds drop and it becomes calm, the eye of the storm may be passing overhead and the wind will soon pick up again from the other direction.

Response and Recovery

Once the storm has passed, there are myriads of immediate concerns. The first community priority is assisting the injured. The uninjured should be encouraged to provide whatever level of care they are trained in and can competently carry out. As a minimum, they can simply identify where injured or trapped individuals are located and help direct responders to focus and accelerate rescue and response operations to those areas. The posthurricane environment can be treacherous. A variety of health and safety threats

result from wind damage and flooding. Community assessments performed by public health in concert with emergency management agencies can provide valuable information on needed services. (CDC, 2002). Downed power lines and damaged building wiring pose electrocution risks. Gas leaks can cause explosions and fire. Broken glass, sharp wood, and metal debris pose injury risks. The area may be littered with tripping hazards that can result in additional injuries (Fig. 14-10). Industrial and household hazardous materials are likely to be spilled during the storm or during clean-up. The roads may be flooded or washed out causing additional driving hazards. Over time, these risks will change. As some risks are remediated, others will emerge. For example, mold growth is a major posthurricane problem. Mold growth is discussed in more detail in the "Floods" chapter of this text.

Loss of homes and nearby healthcare facilities can seriously impact the community reestablishment of home care, long-term care and acute inpatient medical care. Electricity interruptions will impact those who rely on power-assisted devices such as oxygen concentrators, nebulizers, etc. Contamination of potable water sources will impact basic hygiene and health needs. It will also impact those relying on potable water supplies for cooking and items such as baby formula.

FIGURE 14-10 Hurricane Sandy before and after recovery operations at Seaside Heights Pier, New Jersey. *Photograph by Liz Roll, FEMA.*

Communities in recovery are a complex array of systems. The successful recovery of these systems is dependent on the social capital within the community and the ability to use that capital by supporting response and recovery agencies. The comparison of factors influencing the success of recovery from two natural disasters, the tsunami in Sri Lanka and Hurricane Katrina in the United States, demonstrates the impact of social structure in resilience. Sri Lankan traditional social networks provided for resilience in a large-scale devastating event. In many communities in New Orleans, the social networks were not as strong, which created a great deal of dependence on a severely challenged government infrastructure. The resultant lack of resiliency in these New Orleans communities led to long-lasting adverse health and economic outcomes (Munasinghe, 2007; Elliott and Pais, 2006).

Mental and behavioral health support is also vital to a community's long-term recovery. Woods et al. (2014) describe three main themes in the response of survivors who lived through Cyclone Yasi: (1) the sense of panic and feeling at the mercy of nature, (2) feelings of helplessness and chaos, and (3) community support and closeness that helped alleviate losses and uncertainty. A critical finding from this study was the negative role of the media in escalating fears for life prior to and during the cyclone. The disaster also brought communities closer together and connected family, friends, and neighbors through the caring, support, and help offered to each other. These findings highlight the importance of promoting and facilitating social support to aid postdisaster recovery efforts.

Summary

Hurricanes, typhoons, and tropical cyclones carry a variety of acute and long-term public health risks. However, unlike some disaster scenarios where patterns of morbidity and mortality are relatively predictable, hurricanes have many variables, making it difficult to predict health outcomes with any degree of accuracy. Fortunately, more research and analysis are being done on factors contributing to morbidity and mortality in an attempt to identify more-effective mitigation strategies. Although some storms generate a larger number of traumatic injuries and few drowning deaths, others have fewer direct injuries and many more drownings. The severity of storm surge depends on the coastal terrain and the types of community development along the shoreline. These factors also influence the amount of inland flooding but not as much as do the speed and trajectory of the storm. If the weather system moves slowly or stalls, there may be massive quantities of rain causing flooding, as seen during Hurricane Floyd. If the storm moves quickly, as did Hurricane Andrew, there may be little flooding but severe structural damage and subsequent traumatic injuries from high winds. Future preparedness and mitigation strategies must consider both wind and storm surge.

Aside from the levee failure in New Orleans following Hurricane Katrina, the reduction observed in recent years of hurricane-associated morbidity and mortality has been impressive and is a testament to the hard work of meteorologists, emergency management, and local planners. The continued reduction of injuries from these storms can only

be achieved by enhancement and enforcement of building codes, public education on risks and preparedness strategies, and refinement of warning systems. In developing nations, there is still much work to be done in protecting the growing populations of coastal residents. Progress may only be achieved through ongoing international efforts.

What remains to be seen is the long-term effect on extreme weather events related to climate change. Already there appears to be more frequent events, and the Intergovernmental Panel on Climate Change anticipates an increased risk of extreme weather events, especially those such as heat waves, extreme precipitation, and coastal flooding (IPCC, 2014; Paquin et al., 2014). Rising sea levels can also increase the severity of coastal surge during cyclonic storms (Moser et al., 2014). Extreme weather events, such as the 2012 Superstorm Sandy striking the northeast coast of the United States, are likely to occur more frequently in geographic areas that to date rarely experience these events. Preparedness and mitigations strategies must be shared more broadly and continually tailored to address the unique challenges these storms pose around the world.

Websites

American Red Cross, Hurricane Preparedness. http://www.redcross.org/prepare/disaster/hurricane.

Australia, Fire and Emergency Services Authority of Western Australia, Cyclone Preparedness in Northwest Australia. http://www.dfes.wa.gov.au/safetyinformation/cyclone/CycloneResearchPublications/FESA-CyclonePreparednessinNorthWestAustralia.pdf.

Australian Government, Bureau of meteorology, surviving cyclones: Preparation and safety Procedures. http://www.bom.gov.au/cyclone/about/tc-checklist.shtml.

Australian Geographic, The biggest cyclones in recorded history. http://www.australiangeographic.com.au/topics/science-environment/2011/02/the-biggest-cyclones-in-recorded-history/.

Centers for Disease Control and Prevention, Hurricanes. www.emergency.cdc.gov/disasters/hurricanes/index.asp.

Centers for Disease Control and Prevention, Hurricane Response and Cleanup. www.emergency.cdc.gov/disasters/hurricanes/workers.asp.

Environmental Protection Agency, Hurricanes. www.epa.gov/naturalevents/hurricanes.

Federal Emergency Management Agency, Hurricanes. http://www.ready.gov/hurricanes.

Federal Emergency Management Agency, Self-study Course, IS-324.A: Community Hurricane Preparedness. http://www.training.fema.gov/is/courseoverview.aspx?code=IS-324.a.

Fiji Meteorological Service, The Nadi tropical cyclone Centre. http://www.met.gov.fj/.

Florida, The Essential Guide to Hurricane preparedness. http://www.stateofflorida.com/articles/hurricane-preparedness-guide.aspx.

Hong Kong, Labour Department, Code of Practice in Times of Typhoons and Rainstorms. http://www.labour.gov.hk/eng/public/wcp/Rainstorm.pdf.

Hong Kong Observatory, Tropical cyclone. http://www.hko.gov.hk/informtc/tcMain.htm.

National Institute for Occupational Safety and Health: Emergency Response Resources, Storm/Flood and Hurricane/Typhoon response. http://www.cdc.gov/niosh/topics/emres/flood.html.

National Oceanic and Atmospheric Administration, National Climatic Data Center. http://lwf.ncdc.noaa.gov/oa/climate/severeweather/hurricanes.html.

National Oceanic and Atmospheric Administration, National Weather Service, Hurricane Awareness. www.nws.noaa.gov/om/hurricane/index.shtml.

National Oceanic and Atmospheric Administration, National Weather Service, National Hurricane Center. Hurricane Preparedness – Be Ready. http://www.nhc.noaa.gov/prepare/ready.php.

National Oceanic and Atmospheric Administration, National Weather Service, National Hurricane Center, Hurricane Preparedness Week. www.nhc.noaa.gov/HAW2/english/intro.shtml.

University of Rhode Island, Graduate School of Oceanography, Hurricanes: Science and Society. http://www.hurricanescience.org.

University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies. http://cimss.ssec.wisc.edu/.

World Meteorological Organization. http://www.wmo.int/.

World Weather Information Service. http://www.worldweather.org.

References

Burroughs, W.J., World Meteorological Organization, 2003. Climate: Into the 21st Century. Cambridge University Press, Cambridge, U.K.

Centers for Disease Control and Prevention (CDC), 1993. Injuries and illnesses related to Hurricane Andrew—Louisiana, 1992. Morb. Mortal. Wkly. Rep. 42, 242–243 249–251.

Centers for Disease Control and Prevention (CDC), 2000. Morbidity and mortality associated with Hurricane Floyd—North Carolina, September–October 1999. Morb. Mortal. Wkly. Rep. 49 (17), 369–372.

Centers for Disease Control and Prevention (CDC), 2002. Tropical storm Allison rapid needs assessment—Houston, Texas, June 2001. Morb. Mortal. Wkly. Rep. 51, 365–369.

Chowdhury, M., Choudhury, Y., Bhuiya, A., et al., 1992. Cyclone aftermath: research and directions for the future. In: Hossain, H., Dodge, C.P., Abed, F.H. (Eds.), From Crisis to Development: Coping with Disasters in Bangladesh. University Press Ltd, Dhaka, Bangladesh, pp. 101–133.

Combs, D.L., Parrish, R.G., McNabb, S.J., et al., 1996. Deaths related to Hurricane Andrew in Florida and Louisiana, 1992. Int. J. Epidemiol. 25, 537–544.

Deng, Z., Xun, H., Zhou, M., Jiang, B., Wang, S., et al., 2015. Impacts of tropical cyclones and accompanying precipitation on infectious diarrhea in cyclone landing areas of zhejiang province, china. Int. J. Env. Res. Pub. Health 12 (2), 1054–1068.

Diacon, D., 1992. Typhoon resistant housing in the Philippines: the core shelter project. Disasters 16, 266–271.

Duanmu, J., Chowdhury, M., Taffe, K., 2011. A simulation modeling framework for community-wide evacuation planning. J. Transp. Secur. 4, 1–18.

Elliott, J.R., Pais, J., 2006. Race, class, and Hurricane Katrina: social differences in human responses to disaster. Soc. Sci. Res. 35, 295–321.

Emanuel, K., 2005. The great east Pakistan cyclone of November 1970. In: Divine Wind. Oxford University Press, pp. 221–225.

Federal Emergency Management Agency (FEMA), 2010. Wind Retrofit Guide for Residential Buildings. FEMA P-804. Available at: http://www.fema.gov/media-library-data/20130726-1753-25045-2304/508versioncombined_804.pdf.

Federal Emergency Management Agency (FEMA), 2011a. Safe Rooms: Selecting Design Criteria, Tornado Recovery Advisory RA2, June 2011. Available at: http://www.fema.gov/media-library-data/20130726-1801-25045-2230/ra2_2011_storm_shelters_tagged_011912.pdf.

Federal Emergency Management Agency (FEMA), 2011b. Brace Gable End Roof Framing, Protecting Your Property from High Winds. Available at: http://www.fema.gov/media-library-data/20130726-1627-20490-6052/how2018_1__gable_end_roof_4_11.pdf.

Federal Emergency Management Agency (FEMA), 2014. Taking Shelter from the Storm, Building a Safe Room for Your Home or Small Business, FEMA P-320, December 2014. Available at: http://www.fema.gov/media-library-data/1418837471752-920f09bb8187ee15436712a3e82ce709/FEMA_P-320_2014_508.pdf.

Harro-Loit, H., Vihalemm, T., Ugur, K., 2012. Cultural experience as a (Critical) factor in crisis communication planning. J. Con Crisis Manag. 20 (1), 26–38.

Intergovernmental Panel on Climate Change (IPCC) Climate Change, 2014. Impacts, Adaptation and Vulnerability, Summary for Policymakers. WHO. Available at: http://www.ipcc.ch/report/ar5/wg2/.

Langan, J., Palmer, J., 2012. Listening to and learning from older adult Hurricane Katrina survivors. Public Health Nurs. 29 (2), 126–135.

Longshore, D., 1998. Great cyclone of 1970. In: Encyclopedia of Hurricanes, Typhoons, and Cyclones. Facts on File, Inc. Checkmark Books, New York, pp. 147–149.

Moser, S.A., Davidson, M.A., Kirshen, P., et al., 2014. Chapter 25, coastal zone development and ecosystems. In: Climate Change Impacts in the United States: The Third National Climate Assessment. US Global Change Research Program, pp. 579–618. Available at: http://www.globalchange.gov/browse/reports/climate-change-impacts-united-states-third-national-climate-assessment-0.

Munasinghe, M., 2007. The importance of social capital: comparing the impacts of the 2004 Asian Tsunami on Sri Lanka, and Hurricane Katrina 2005 on New Orleans. Ecol. Econ. 64 (1), 9–11.

National Oceanic and Atmospheric Administration, National Hurricane Center (NHC) Miami, and National Climatic Data Center (NCDC) Asheville, August 2011. The Deadliest, Costliest, and Most Intense United States Tropical Cyclones from 1851 to 2010 (And Other Frequently Requested Hurricane Facts). NOAA Technical Memorandum NWS NHC-6 National Weather Service National Hurricane Center, Miami, Florida. Available at: http://www.nhc.noaa.gov/pdf/nws-nhc-6.pdf.

National Oceanic and Atmospheric Administration, National Hurricane Center (NHC), 2015. Hurricane Preparedness – Hazards, Storm Surge & Storm Tide. Available at: http://www.nhc.noaa.gov/prepare/hazards.php.

National Oceanic and Atmospheric Administration, National Ocean Service (NOS), 2015. Natural Resource Restoration. Available at: http://oceanservice.noaa.gov/ecosystems/restoration/welcome.html.

Noji, E.K., 1993. Analysis of medical needs during disasters caused by tropical cyclones: anticipated injury patterns. J. Trop. Med. Hyg. 96, 370–376.

Nirupama, N., 2013. Vertical evacuation during cyclones: suitable for developing counties. Nat. Hazards 69, 1137–1142.

Paquin, D., de Elias, R., Frigon, A., 2014. Change in North American atmospheric conditions associated with deep convection and severe weather using CCCM4 climate projections 2014. Atmosphere-Ocean 52 (3), 175–190.

Rice, D., August 31, 2005. Hurricane Katrina stronger than Andrew at landfall. USA Today. Available at: www.usatoday.com/weather/stormcenter/2005-08-31-Katrina-intensity_x.htm.

Rotheray, K.R., Aitken, P., Goggins, W.B., Rainer, T.H., Graham, C.A., 2012. Epidemiology of injuries due to tropical cyclones in Hong Kong: a retrospective observational study. Injury 43 (12), 2055–2059.

Stewart, R.H., 2005. Introduction to Physical Oceanography. Department of Oceanography, Texas A&M University. On-Line Textbook, (Chapter 4). Available at: http://oceanworld.tamu.edu/resources/ocng_textbook/contents.html.

Toole, M.J., 1997. Communicable disease and disease control. In: Noji, E.K. (Ed.), The Public Health Consequences of Disasters. Oxford University Press, New York, pp. 79–100.

Townsend, F.F., 2006. The federal response to Hurricane Katrina lessons learned. White House. Available at: www.whitehouse.gov/reports/katrina-lessons-learned.pdf.

United Nations Children's Fund (UNICEF), September 15, 2005. At a Glance: United States of America, Katrina: One Family's Survival Story. Available at: www.unicef.org/infobycountry/usa_28275.html.

United Nations Development Programme (UNDP), 2012. Reducing Disaster Risk: A Challenge for Development. John S. Swift Company, New York. Available at: http://www.undp.org/content/undp/en/home/librarypage/crisis-prevention-and-recovery/reducing-disaster-risk–a-challenge-for-development.html.

Western, K., 1982. Epidemiologic Surveillance after Natural Disaster. Pan American Health Organization, Washington, DC. PAHO Scientific Publication No. 420. Available at: http://helid.digicollection.org/en/d/Jph09ee/.

World Meteorological Organization (WMO), 2015. Tropical Cyclone Naming. Available at: http://www.wmo.int/pages/prog/www/tcp/Storm-naming.html.

World Meteorological Organization (WMO), Tropical Cyclone Programme, 2008 Edition. Technical Document WMO/TDNo. 292, Report No. TCP24, Tropical Cyclone Operational Plan for the South Pacific and Southeast Indian Ocean. Available at: http://www.wmo.int/pages/prog/www/tcp/documents/TCP24-English2008.pdf.

World Meteorological Organization (WMO), Tropical Cyclone Programme, 2010 Edition. Technical Document WMO/TDNo. 84, Report No. TCP21, Tropical Cyclone Operational Plan for the Bay of Bengal and the Arabian Sea. Available at: http://www.imd.gov.in/section/nhac/dynamic/TCP-21.pdf.

Woods, C., West, C., Buettner, P., Usher, K., 2014. 'Out of our control': living through cyclone Yasi. Int. J. Qual. Stud. Health Well-being 9. Available at: http://www.ijqhw.net/index.php/qhw/article/view/19821.

15

Nuclear and Radiological Disasters

OBJECTIVES

- Explain the difference between ionizing and nonionizing energy.
- Recognize the primary units of measurement for radiation.
- Describe the risks associated with different various types of radiation.
- Explain the stages and effects of acute radiation syndrome.
- List the effects of a nuclear detonation.
- Describe the difference between an improvised nuclear device and a dirty bomb.
- List the factors that determine the morbidity and mortality of a dirty bomb.
- Explain what can be done to reduce the threat of nuclear and radiological weapons.
- Describe the three most important protective factors when dealing with radiation.
- List the key issues hospitals must consider when planning for radiological disasters.

Introduction: 1986 Chernobyl Nuclear Accident

In April 1986, a small city in Ukraine became the focus of international concern and the site of the largest technological disaster in history. The Chernobyl Nuclear Power Station was constructed in the 1970s and consisted of four reactors. The first reactor, Reactor Number 4, started generating power in 1983. Others were in various stages of construction in 1986 when a nuclear catastrophe occurred. A routine test was under way to determine whether Reactor Number 4 could keep cooling pumps operating during a power outage until the backup generators could activate. A power surge during the test led to a massive explosion in the reactor setting a meltdown in motion (see Fig. 15-1) (USNRC, 2013). The fuel rods and graphite reactor cover melted through the floor, and a huge cloud of radiation was released. The amount released has been described as 30–40 times the amount of radiation released from the detonation of the Hiroshima and Nagasaki atomic bombs (LOC, 1996).

The groups at risk from Chernobyl radiation exposures have been studied by dividing them into several groups, including "liquidators" or those who responded and conducted on-site response and clean-up, evacuees from the "highly contaminated" zone, residents of the "strict-control" zones, and residents of other contaminated areas beyond the control zones. These areas span across Ukraine, Belarus, and Russia. However, measurable contamination from Chernobyl was detected in nearly every nation in the Northern Hemisphere (UN, 1988b).

The initial populations exposed were plant personnel and first responders. These individuals received whole body gamma irradiation, substantial skin exposure to beta radiation, and inhalation of a variety of nuclides including radioiodine and cesium. Just

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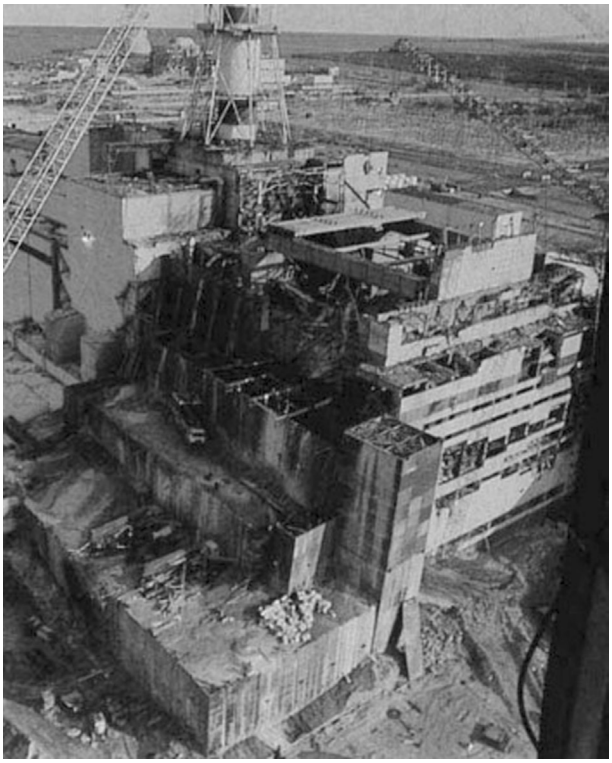

FIGURE 15-1 Chernobyl Nuclear Power Station following the April 1986 explosion. *Photograph courtesy of the U.S. Nuclear Regulatory Commission.*

over 200 workers were involved in the initial response, and more than half of them suffered from acute radiation syndrome (ARS). Over the next 3 weeks, 19 died (UN, 1988a). In the 4 months following the accident, a total of 28 facility workers and responders died from their exposures (USNRC, 2006).

Hundreds of thousands were recruited to carry out clean-up operations (see Fig. 15-2). To limit the exposure of individual workers, each person would work a shift of several minutes and quickly move out as the next crew came in to work several minutes. As individuals reached their limit for "allowable" exposures, more workers would be brought in as replacements. Besides the initial workers and responders who were present during and immediately after the explosion, these "liquidators" received the most significant radiation exposures. Most were 20–45 years old at the time of the accident. There are ongoing debates over the health impact among these workers. While some claim tens of thousands have died from illnesses related to their exposures, the International Atomic Energy Agency claims the morbidity and mortality studies carried out among the liquidators show no correlation between their exposures at Chernobyl and their cancer and death rates (IAEA, 2005).

The other groups observed for radiological health effects include evacuees from the area immediately surrounding the facility and those who reside in potentially contaminated

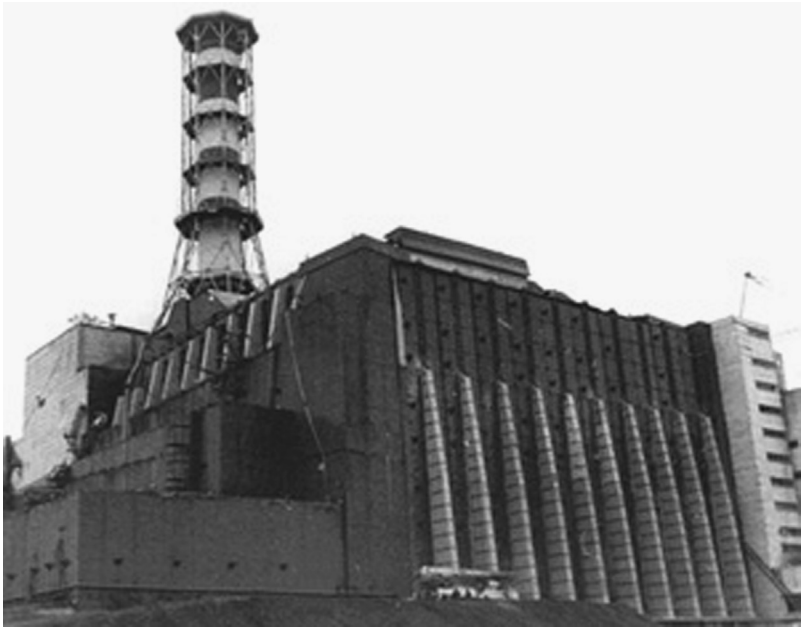

FIGURE 15-2 The "sarcophagus" built to entomb Reactor Number 4 and the radioactive remains. *Photograph courtesy of the U.S. Nuclear Regulatory Commission.*

Table 15-1 Average Accumulated Dose of Chernobyl-Affected Populations Compared to Natural and Medical Radiation Sources (Cardis, 2005; HPS, 2010)

Population	Number Exposed	Exposure Timeframe	Average Dose (mSv)
Recovery workers ("liquidators")	240,000	1986–1987	100
Evacuees from contaminated zone	116,000	1986	33
Residents of strict control zones	270,000	1986–2005	50
Residents of other contaminated areas	5,000,000	1986–2005	10
Naturally occurring background levels	All	1986–2005	48
Medical: chest radiograph	N/A	Per procedure	0.1
Medical: mammogram (two views)	N/A	Per procedure	0.36
Medical: head CT	N/A	Per procedure	2.0
Medical: whole body CT	N/A	Per procedure	10.0
Medical: coronary angiography	N/A	Per procedure	20.0

areas. Besides the direct exposure to the initial radioactive plume emitted from the facility, area residents have received additional exposure from contaminated food, water, and air over the years following the disaster. Eating food grown in contaminated soil and drinking milk from cows grazing on contaminated grass have increased the exposure of those living throughout the region, but not significantly (see Table 15-1). However, there is evidence of increased thyroid cancers among exposed children (Cardis et al., 2006), although some

claim the increases are the result of enhanced surveillance activities and do not represent a true increase (Moysich et al., 2002).

The United Nations Scientific Committee on the Effects of Atomic Radiation is composed of a staff of 15, a committee of 146, and 21 national delegations (Jaworowski, 2001). This committee is considered by many to be the most knowledgeable and objective collection of nuclear experts in the world. With the exception of increased thyroid cancers among exposed children, the committee has not seen compelling evidence of any serious health problems resulting from Chernobyl. However, the low demonstrated increases do not suggest there is no risk as there has not been adequate study of the exposed populations. The power of existing published studies is low and methods used have limitations (Cardis et al., 2006). Based on current knowledge, a small increase in relative risk is anticipated.

Chronic doses of radiation are cumulative over each person's lifetime and are known to cause thyroid cancer, leukemia, solid cancers, circulatory disease, cataracts, and birth defects. There are several possible reasons why these health conditions are not detected in the exposed population as dramatically as many public health experts predicted. First, there still may be changes in health status among the exposed yet to occur. Several of these conditions develop slowly over time and the differences between those exposed and those not exposed may not become apparent for several more years. Second, there is ongoing mistrust of authorities and some doubt if results showing substantial increases in latent radiological morbidity and mortality will be shared with the international community. Finally, there may, in fact, not be the predicted long-term morbidity and mortality. If this is the case, there will still be many conspiracy theorists and others steeped in their own dogma who will never believe the expected health outcomes do not exist.

The psychological impact of Chernobyl may carry the most significant health impact of all. The nature of radiation exposure is frightening. Radiation cannot be seen or detected with any of the human senses and the damage caused by radiation can take decades to emerge. When radiation damage appears, it could be in the form of a terminal cancer resulting in an extended time of suffering. It can also impact future generations and those exposed will worry for themselves as well as for their children. When this scenario is coupled with the propensity for much of regional political leadership to misinform the public and deny problems, it is a recipe for long-term stress, which will undoubtedly contribute to the overall morbidity and mortality of Chernobyl.

Efforts continue to contain and manage the aftermath of the Chernobyl tragedy. The site of the explosion still poses a significant radiological threat to the environment. The decaying structure contains >100 tons (>220,000 pounds) of uranium and 1 ton (>2200 pounds) of plutonium, along with many more contaminants. A project called "New Safe Confinement" has been launched to contain the site inside an enormous structure weighing 31,000 tons (>68 million pounds) and costing >1.5 billion euros (see Fig. 15-3) (Shukman, 2015). The structure is designed to contain the contamination for at least a century.

FIGURE 15-3 New Safe Confinement under construction in April 2015. Seen are the two sections joined together and nearing completion. *Photograph by Tim Porter.*

Although Chernobyl was the first catastrophic reactor failure, it was preceded by other accidents. In 1957, Windscale Number 1, the first large reactor built in the United Kingdom experienced a fire but no explosion. Radiation was released across England. In 1961, an experimental reactor in Idaho experienced an explosion, killing three servicemen and contaminating the facility and surrounding area. In both cases, the reactors were closed and abandoned. Walter Patterson, a nuclear expert and author, has made some interesting comparisons of these incidents to Chernobyl (Patterson, 1986). There are three things each of these accidents has in common:

1. Equipment failed or processes did not work as planned.
2. Human error made the situation worse.
3. The public seldom received accurate information in the immediate aftermath.

Nuclear and Radiological Disaster Definitions

Absorbed dose The amount of energy deposited by ionizing radiation in a mass of tissue expressed in units of joule per kilogram (J/kg) and called "gray" (Gy).

Acute exposure Exposure to radiation that occurs in a matter of minutes.

Alpha radiation (alpha particle) A positively charged particle consisting of two neutrons and two protons. It is the least penetrating but most ionizing of the three common forms of radiation. Alpha radiation can be stopped by a sheet of paper but can cause significant long-term damage if inhaled or ingested. It carries more energy than beta or gamma radiation.

Acute radiation syndrome (ARS) A serious, often fatal illness resulting from exposure to a high dose of penetrating radiation to the body in a short time (usually minutes). Also called "radiation sickness."

Background radiation Radiation from the natural environment originating primarily from the natural elements in rock or soil and from the cosmic rays.

Becquerel (Bq) The amount of a radioactive material that undergoes one decay (disintegration) per second.

Beta radiation (beta particle, beta ray) An electron of either positive or negative charge that has been ejected by an atom in the process of a transformation. Beta particles are more penetrating than alpha radiation but less than gamma. They can cause serious skin burns with high exposures.

Cumulative dose The total dose that accumulates from repeated or continuous exposures of the same part of the body, or of the whole body, to ionizing radiation.

Curie (Ci) The traditional measure of radiation based on the observed decay rate of 1 g of radium.

Cutaneous radiation syndrome A complex syndrome resulting from excessive ionizing radiation exposure to the skin. The immediate effects can be reddening and painful swelling of the exposed area. Large doses can result in permanent hair loss, scarring, altered skin color, deterioration of the affected body part, and death of the affected tissue (requiring surgery).

Decay (radioactive) The change of one radioactive nuclide into a different nuclide through the spontaneous emission of alpha, beta, or gamma rays or by electron capture. The end product is a less-energetic, more-stable nucleus.

Decontamination The removal of radioactive contaminants by cleaning and washing.

Dirty bomb A device designed to spread radioactive material by the explosion of a conventional device. A dirty bomb is relatively simple to make and kills or injures people through the initial blast of the conventional explosive while also spreading radioactive contamination. Also referred to as a radiological dispersion device (RDD).

Fissile An atom or element able to achieve nuclear fission.

Fission The splitting of a heavy nucleus into two roughly equal parts accompanied by the release of a relatively large amount of energy in the form of neutrons and gamma rays. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

Gamma A highly penetrating type of nuclear radiation, similar to X-radiation except it comes from the nucleus of an atom. Gamma rays penetrate tissue farther than beta or alpha particles but leave a low concentration of ions in their path to damage cells.

Geiger counter A Geiger–Müller detector and radiation measuring instrument containing a gas-filled tube that discharges electrically when ionizing radiation passes through it and a device that records the events. They are the most commonly used as portable radiation detection instruments.

Gray (Gy) A unit of measurement for the absorbed dose of radiation. The unit Gy can be used for any type of radiation, but it does not describe the biological effects of the different types of radiation.

Improvised nuclear device (IND) A nuclear weapon built by a rogue nation or terrorist organization with illegally acquired fissile materials; A nuclear weapon bought, stolen, or provided by a nation with a nuclear program to a rogue nation or terrorist organization.

Ion An atom with more (or fewer) electrons than protons, resulting in an electrical charge that makes it chemically reactive.

Ionization The process of adding one or more electrons to, or removing them from, atoms or molecules, thereby creating ions.

Ionizing radiation Radiation capable of displacing electrons from atoms, thereby producing ions. High doses of ionizing radiation can produce severe skin or tissue damage.

Isotope An element with the same atomic number but different atomic weights (different number of neutrons in their nuclei). Uranium-238 and uranium-235 are isotopes of uranium.

Latent period The time between exposure to a dangerous material and the appearance of a consequential health effect.

Nonionizing radiation Radiation with lower energy levels and longer wavelengths than ionizing radiation. This type of radiation poses danger through producing heat in tissue but does not affect the structure of atoms. (eg, radio waves, microwaves, visible light, and infrared from a heat lamp).

Nuclear energy Heat energy produced by nuclear fission inside a nuclear reactor or by radioactive decay.

Protective Action Guide (PAG) A guide informing responders and authorities at what projected dose they should take action to protect people from accidental or intentional radiation releases in the environment.

Radiation Energy moving in the form of particles or waves. Familiar radiations include radio waves, microwaves, heat, and light. Ionizing radiation is a high-energy form of electromagnetic radiation.

Radiation absorbed dose (rad) The basic unit of absorbed radiation dose. It is a measure of the amount of energy absorbed by the body. The rad is the traditional unit of absorbed dose. However, it has been replaced by the unit Gy, which is equivalent to 100 rad.

Radioactive decay The spontaneous disintegration of an atom's nucleus.

Radioactivity The process of spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles, often accompanied by gamma rays. This process is referred to as decay or as the disintegration of an atom.

Radiological dispersion device (RDD) A device designed to spread radioactive material by the explosion of a conventional device. It is relatively simple to make and kills or injures people through the initial blast of the conventional explosive while also spreading radioactive contamination. Also refers to a dirty bomb.

Roentgen A unit of radiation exposure defined as the amount of X- or gamma-radiation, which produces 1 electrostatic unit of charge in 1 cubic centimeter of dry air under normal conditions.

Roentgen equivalent, man (rem) A unit of equivalent dose. Not all radiations have the same biological effect, even for the same amount of absorbed dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. Although it is the traditional unit of equivalent dose, it has been replaced by the sievert (Sv), which is equal to 100 rem.

Shielding Material used as a barrier between a radiation source and a potentially exposed person to reduce exposure.

Sievert (Sv) The international standard unit for the amount of ionizing radiation required to produce the same biological effect as 1 rad of high-penetration X-rays, equivalent to a gray for X-rays. (100 rem or 8.38 R). This relates to the absorbed dose in human tissue, which varies by the type of radiation. Doses are usually expressed in millionths of a sievert or microsieverts.

Teratogenic effect Birth defects resulting from chemical or radiation exposures of a fetus.

Basic Facts About Nuclear and Radiological Threats

For decades, military personnel around the world were trained in nuclear, biological, and chemical (NBC) or chemical, biological, and radiological (CBR) defense. In fact, several decades ago, the U.S. Army used NBC while the U.S. Navy used CBR to describe the same training. Those terms evolved and in more recent years, the distinction was drawn between nuclear and radiological events leading to a new acronym. Chemical, biological, radiological, and nuclear (CBRN) has become the common term and acronym for weapons of mass destruction or weapons of mass effect among preparedness and response professionals delineating the differences between nuclear and radiological accidents or acts of terrorism.

A nuclear event is distinguished by a nuclear detonation or fission. This includes nuclear bombs and smaller improvised nuclear devices (INDs), which release blinding light and a blast wave with intense thermal heat and radiation. A radiological event does not involve a fission reaction or nuclear explosion. Radiological events include accidents at nuclear facilities or with radiological materials in transport. It can also

describe two radiological terrorism scenarios. A hidden radioactive source can be placed where people are exposed to dangerous levels of radiation, or if an explosive device is added to a radioactive source, it can be used as a radiological dispersion device (RDD), or dirty bomb. The distinction between these events is important to preparedness and response planning. Responding to a nuclear event is far different than responding to a radiological event.

Radiation is simply a form of electromagnetic energy. Energy with different wave lengths has different applications and effects, and the entire spectrum is typically divided into seven subsections including radio, microwave, infrared, visible, ultraviolet, X-ray, and gamma ray (see Fig. 15-4). The most important difference between these forms of energy is the ionizing potential. At lower frequencies, from radio through ultraviolet energy, the energy is nonionizing. As the frequency increases, the energy becomes ionizing. This means the energy gains the ability to remove an electron from an atom or a molecule. When this happens to water molecules inside the body, it creates highly oxidizing free radicals. These free radicals damage various parts of living cells resulting in cell death, inhibition of cell division, or the production of abnormal or malignant cells.

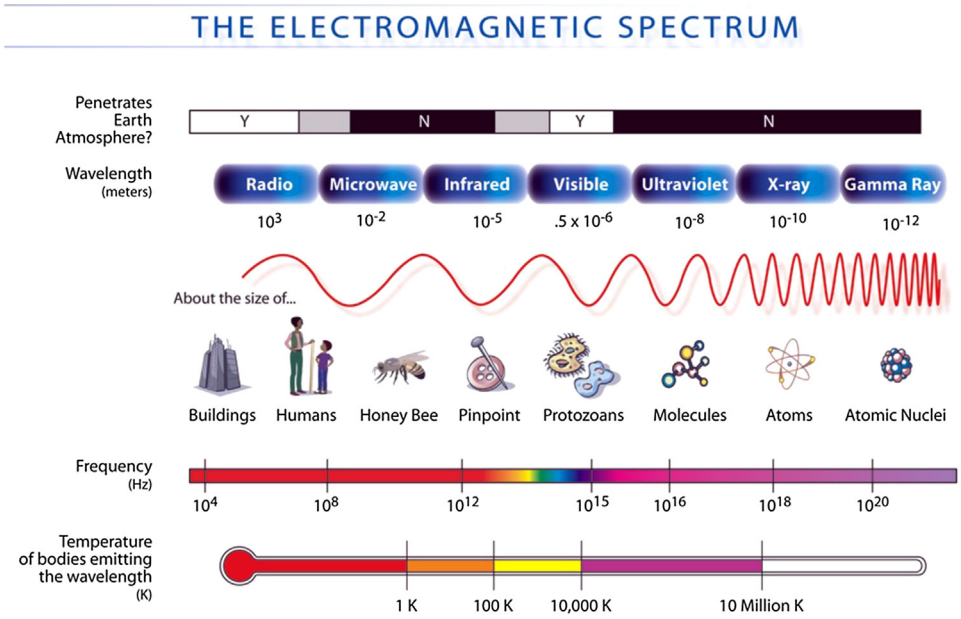

FIGURE 15-4 The electromagnetic spectrum. *Image courtesy of the National Aeronautics and Space Administration.*

The terms used to express radiological units of measure have been adopted internationally (gray, centigray, sievert, centisievert, and becquerel), but many references are still made to the previous terms for the units of measure (rad, rem, roentgen, and curie). The dual use of old and new terms will continue to cause confusion across the scientific community until the international values are completely adopted.

The relationships between the older units of measurement and the international values are as follows (Figley, 1980):

- 1 Gy = 1 J/kg = 100 rad
- 1 cGy = 1 rad
- 1 sievert (Sv) = 100 rem
- 1 centisievert = 1 rem
- 2.58×10^{-4} C/kg = 1 R
- 1 becquerel (Bq) = 1 nuclear transformation per second = 2.7×10^{-11} Ci

Ionizing radiation exposures are measured by the amount of absorbed energy per unit of mass. The unit of absorbed dose is Gy. It represents a joule per kilogram (J/kg). If the total absorbed dose in a person exceeds 1 Gy, it can result in ARS. Since there are so many different levels of susceptibility among the organs of the body, another measurement is used to describe the effective dose. This is called a sievert. It is a measurement that takes into account the type of radiation, susceptibility of the most sensitive organs, internal versus external exposures, and uniform versus nonuniform exposures. One sievert is considered to be a very large exposure, and so millisieverts (mSv), or thousandths of a Sv, are used to describe typical exposures. For example, in Table 15-1, the 20-year background radiation exposure is based on the United Nations Scientific Committee on the Effects of Atomic Radiation estimates, which indicate the average annual exposure of a human to natural background radiation is 2.4 mSv (Cardis, 2005).

There are four primary types of radiation: alpha, beta, gamma, and X-ray. Each radiation type has a different origin or poses unique health threats to those exposed (Fig. 15-5). During radioactive decay, all four radiation types can be present.

- Alpha radiation is a large particle compared to the other particulate radiological threats. Examples of alpha emitters include radon and uranium. Alpha radiation is not able to penetrate human skin and poses no external hazard. However, as a larger particle, it poses a significant internal threat. If the particles are inhaled, ingested, or absorbed through an open wound, they can irradiate surrounding living cells and pose chronic health risks. Alpha particles can only travel several inches in the air. There are a variety of detection devices available but they must be within a couple inches of the alpha source with no interferents, including heavy dust or water.
- Beta radiation is also a particle. Examples of beta emitters include carbon-14 and strontium-90. These particles consist of ejected electrons and can travel several feet. Beta particles are much smaller than alpha particles and can penetrate several layers of skin cells resulting in "beta burns." Beta radiation can also pose an internal hazard. Beta particles cannot be stopped by a sheet of paper like alpha particles, but they can be stopped by a sheet of plywood. Clothing provides some protection, though not complete. Beta radiation can be detected using specific beta survey instruments, but some beta emitters produce such low energy they are difficult to detect with current instrumentation.

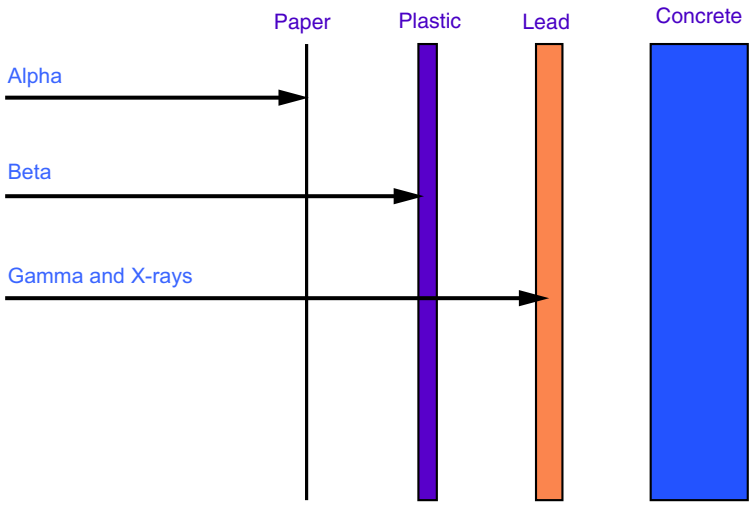

FIGURE 15-5 Relative penetrating power of radiation types. *Image courtesy of the U.S. Department of Energy*

- Gamma radiation and X-rays are highly penetrating radiation. They consist of electromagnetic energy able to penetrate most surfaces. In many ways, they are like radio waves or ultraviolet light, only with much more energy. This type of radiation can travel many feet in the air and through several inches of human tissue. Exposure to gamma radiation can result in acute or chronic injuries. Examples of gamma emitters include cesium-137 and cobalt-60. There are a variety of gamma radiation detection devices available.

With radiation taking on two primary forms, particulate and energy, there are two primary types of exposures possible: irradiation and contamination. During different types of nuclear and radiological accidents or attacks, one or both of these types of exposures may occur.

Irradiation occurs when gamma or X-ray radioactive energy passes directly through the body. This causes rapid cellular damage and can make a person sick almost immediately with higher doses causing a more rapid onset of symptoms. The resulting acute illness is called ARS. Irradiation can also lead to chronic health problems. Damage to an exposed person's DNA can also lead to chronic illnesses such as cancer and birth defects. Many of the survivors of the atomic bomb attacks during World War II and the initial responders at Chernobyl experienced both ARS and long-term health concerns.

Contamination is direct contact with radioactive material. When a radioactive source, solid or liquid, is retained on a surface, it is contaminated. If the contaminated surface comes in contact with other surfaces, it can continue to spread the contamination. If the radioactive contamination is inhaled, ingested, or penetrates the skin,

it is transported throughout the body where it irradiates surrounding cells. Although contamination does not usually cause ARS, it can produce chronic illnesses such as cancer.

Human Health Effects

Acute Radiation Syndrome (ARS) is one of the most challenging aspects of a public health and medical response to a nuclear or radiological incident. This condition is the result of a large exposure to a penetrating external radiation source over a short period of time. ARS includes four stages. A prodromal stage with gastrointestinal symptoms such as nausea, vomiting, and diarrhea can begin within minutes or days of the exposure and last up to several days. A latent stage follows in which the patient feels fine for a period of time ranging from hours to weeks. This latent stage is followed by a manifest illness stage, which includes one or more of three classic syndromes (CDC, 2005a):

- Bone marrow syndrome often leading to death from the destruction of bone marrow resulting in infections and hemorrhage
- Gastrointestinal syndrome likely leading to death from serious gastrointestinal tract damage causing infections, dehydration, and electrolyte imbalance
- Cardiovascular/central nervous system syndrome leading to death within a few days from circulatory system collapse and increased intracranial pressure from edema, vasculitis, and meningitis

The final stage is either recovery or death. The entire process can take from a few weeks to a couple years. Table 15-2 provides additional details on the progression of each syndrome.

ARS usually involves such a large external radiation exposure that it includes cutaneous radiation injury (CRI) as well (Figs. 15-6 and 15-7). CRI can also occur with no association to ARS. In fact, CRI is most often found in people who have come in direct contact with an industrial radiation source. There is usually a delay between the exposure and the onset of symptoms and the progression is in stages, similar to ARS. There is a prodromal, latent, and manifest illness stage, sometimes followed by a third wave before recovery (CDC, 2005b). Skin problems at the CRI site can reemerge in months and years following recovery and may include skin cancer.

There are also special challenges in managing pregnant patients exposed to radiation. Although the fetus or embryo receives a lower exposure than the mother due to the protection of the mother's body, they are also far more vulnerable to the consequences of a radiation exposure. Since cells are dividing quickly in the growing fetus, the DNA and cellular damage resulting from radiation exposure can cause to birth defects, growth retardation, impaired brain function, and cancer (CDC, 2005c). Managing these exposures requires a team of specialists including a health physicist to assist in determining the dose experienced.

Table 15-2 ARS Doses and Stages

	Bone Marrow Syndrome	Gastrointestinal Syndrome	Cardiovascular/Central Nervous System Syndrome
Mild symptoms may begin	0.3 Gy (30 rad)	6 Gy (600 rad)	20 Gy (2000 rad)
Typical dose resulting in syndromes[a]	>0.7 Gy (>70 rad)	>10 Gy (>1000 rad)	>50 Gy (5000 rad)
Prodromal stage	Symptoms include anorexia, nausea, and vomiting. Onset in 1 hours–2 days after exposure. Stage lasts from minutes to days.	Symptoms are anorexia, severe nausea, vomiting, cramps, and diarrhea. Onset occurs within a few hours after exposure. Stage lasts about 2 days to 1 week.	Symptoms are extreme nervousness and confusion; severe nausea, vomiting, and watery diarrhea; loss of consciousness; and burning sensations of the skin. Onset occurs within minutes of exposure. Stage lasts for minutes to hours.
Latent stage	Stem cells in bone marrow are dying, although patient may appear and feel well. Stage lasts 1–6 weeks.	Stem cells in bone marrow and cells lining GI tract are dying, although patient may appear and feel well. Stage lasts less than 1 week.	Patient may return to partial functionality. Stage may last for hours but usually is less.
Manifest illness stage	Symptoms are anorexia, fever, and malaise. Drop in all blood cell counts occurs for several weeks. Primary cause of death is infection and hemorrhage. Most deaths occur within a few months.	Symptoms are malaise, anorexia, severe diarrhea, fever, dehydration, and electrolyte imbalance. Death is due to infection, dehydration, and electrolyte imbalance. Death occurs within 2 weeks of exposure.	Symptoms are return of watery diarrhea, convulsions, and coma. Onset occurs 5–6 hours after exposure. Death occurs within 3 days of exposure.
Recovery stage	In most cases, bone marrow cells will begin to repopulate the marrow. There should be full recovery for a large percentage of individuals from a few weeks up to 2 years after exposure. Death may occur in some individuals at 1.2 Gy (120 rad). The LD50/60[b] is about 2.5–5 Gy (250–500 rad).	LD100[c] is about 10 Gy (1000 rad).	No recovery expected

[a]All absorbed doses listed are "gamma equivalent" values.

[b]The LD50/60 is the dose necessary to kill 50% of the exposed population in 60 days.

[c]The LD100 is the dose necessary to kill 100% of the exposed population.

Adapted from the Centers for Disease Control and Prevention, Acute Radiation Syndrome: A Fact Sheet of Physicians. Available at: http://www.bt.cdc.gov/radiation/arsphysicianfactsheet.asp.

FIGURE 15-6 A cutaneous radiation injury from a fluoroscopy nearly 6 months after an exposure estimated at about 20 Gy. *Photograph courtesy of the Food and Drug Administration.*

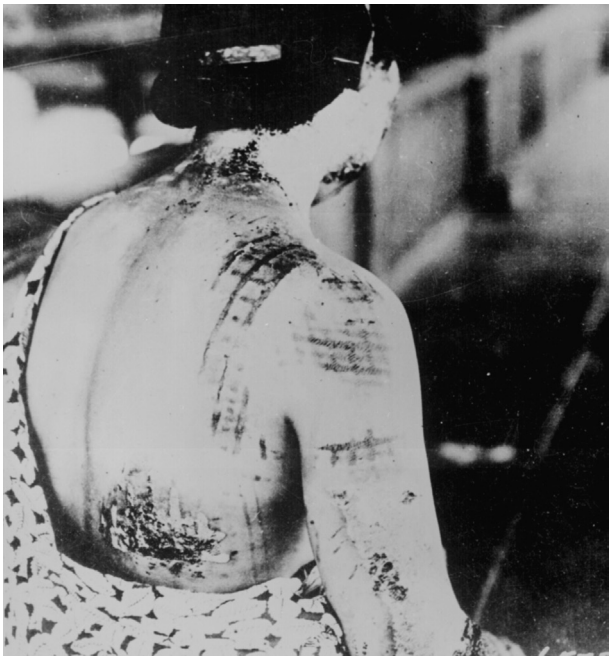

FIGURE 15-7 The victim of an atomic bomb with her skin burned in a pattern corresponding to the dark portions of a kimono worn at the time of the explosion. *Photograph courtesy of the U.S. National Archives.*

Nuclear and Radiological Accidents versus Terrorism

The United States' Department of Homeland Security developed 15 National Planning Scenarios in 2005. The scenario topics range from natural disasters and pandemics, to terrorist attacks using chemical, biological, radiological, and nuclear weapons. They serve as planning tools by providing credible scenarios for developing a range of response capabilities. Scenario number 1 is the detonation of a 10-kiloton improvised nuclear device (IND), and scenario number 11 is an attack using the radiological dispersion device (RDD) (DHS, 2006). These scenarios are very distinct in terms of the challenges posed and fundamentally different from industrial accident scenarios. In fact, there are five distinct differences:

- Most radiological emergency planning is focused on nuclear power facility accidents that are much smaller events than an IND and would not include the same blast and heat hazards.
- Due to the alarm systems in place at modern nuclear facilities, most radiological accident scenarios will have several hours of warning before a release begins. IND or RDD attacks are more likely to be unannounced.
- The IND or RDD incident is more likely to happen in a densely populated area and most nuclear reactors are located in rural areas. Fewer people and less infrastructure will be affected by an accident than an attack.
- Nuclear facilities have detailed preparedness plans and hold regular exercises. Tremendous resources are expended on nuclear facility preparedness. The management of a nuclear facility emergency is likely to be much better coordinated than a response to an attack.
- The type of radiological material involved in a nuclear facility accident is likely to be different from what would be seen with the IND or RDD attack.

A nuclear detonation releases energy in three forms: blast, thermal, and ionizing radiation. Fifty percent of the energy is released in the blast as a crushing overpressure and hurricane-like wind. Thirty-five percent is released as intense heat. The remaining 15% is released as ionizing radiation with about 5% being released instantly as gamma and the remaining 10% in the fallout (Fig. 15-8). This means the initial detonation will instantly release so much energy that anyone looking toward it will likely be blinded. While light surfaces will reflect the flash, darker surfaces will absorb heat from it as shown in Fig. 15-7 where the pattern of the woman's clothing was burned onto her skin when the lighter fabric reflected the flash and the darker material absorbed it.

After the initial flash, a Mach stem, or crushing change in atmospheric pressure traveling at the speed of sound, will precede the blast winds. As quickly as the overpressure strikes everything in its path, hurricane-force winds with searing heat will follow quickly behind (Fig. 15-9). At the same time, a large amount of radiation is released resulting in ARS cases for those near the detonation who survive the initial explosion. A fallout cloud will then carry radiation many miles downwind of the detonation site posing a chronic health risk to many more people for an extended period of time.

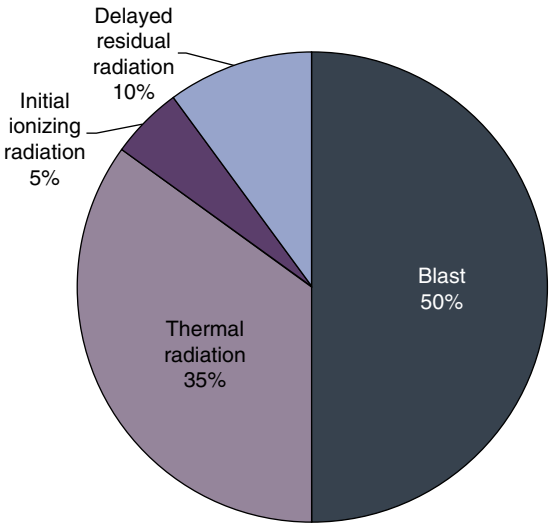

FIGURE 15-8 Nuclear weapon detonation effects. *U.S. Armed Forces Radiobiology Research Institute.*

FIGURE 15-9 The PRISCILLA Event, conducted at the Nevada Test Site, June 24, 1957, was a 37-kiloton device exploded from a balloon. *Photograph courtesy of National Nuclear Security Administration/Nevada Site Office.*

The types of injuries resulting from a nuclear detonation include primary blast injuries from the overpressure, secondary traumatic injuries from the debris propelled by the blast, tertiary injuries from people being thrown and from collapsing structures, and quaternary injuries such as burns. The flash of the fireball will result in retinal burns, which will vary by distance from the explosion. There will also be direct and indirect burn injuries. Radiation will have both immediate effects for individuals with acute radiation illness and long-term effects over a much larger area for those in the path of fallout who inhale or ingest radioactive particles.

The RDD poses a very different scenario. Although there is an explosion associated with some RDDs, they have no nuclear reaction or fission. The RDD has an explosion thousands of times smaller than a nuclear detonation. A "dirty bomb" is one type of RDD consisting simply of an explosive device paired with radiological material. The most immediate health impact of an RDD is blast injury. As first responders arrive at the scene of a mysterious explosion, they will use standard detection equipment to identify the radiological threat. The level of risk to human health extending beyond the initial blast injuries will be determined by the quantity and type of radiological material used as well as a variety of other environmental and response variables.

Dirty Bombs: Morbidity and Mortality Impact Factors

1. Type of radioactive material (alpha, beta, or gamma emitter)
2. Amount of radiological material
3. Size of explosion
4. Type of individual exposures (internal or external)
5. Time of individual exposure to radioactive material
6. Distance of individuals from explosion
7. Shielding of individuals at risk (indoors or outdoors)
8. Weather and wind patterns
9. Decontamination, evacuation, and sheltering effectiveness
10. Availability and efficacy of chelating agents and other drugs

Prevention

Prevention of nuclear or radiological incidents, both accidental and intentional, depends on control of radiological material. Careful security and administrative controls are needed for all existing radiological sources, which could be used in INDs or dirty bombs. It is also important that the international community continues to press all nuclear capable nations to abide by the Nuclear Non-Proliferation Treaty (NPT). The treaty has been signed by 191 nations over the past 40 years and expresses support for nonproliferation of nuclear weapons programs, disarmament, and use of nuclear technologies for energy and other peaceful applications (United Nations Office for Disarmament Affairs, 1968). Although the five declared nuclear states (China, France, Russia, United Kingdom, and United States) have signed the NPT, three known nuclear powers (India, Pakistan, and Israel) have refused to sign the treaty. In addition, nations pursuing nuclear programs include North Korea, Syria, and Iran. Those nations not standing with the international community to limit the proliferation of nuclear programs will continue to heighten the risk for nuclear and radiological accidents and attacks (Arms Control Association, 2007).

In addition to nations with nuclear weapons programs, dozens of other nations have weapons-usable material, which could be used for the development of INDs or RDDs. The

most essential radiological materials to build nuclear weapons (plutonium and highly enriched uranium or HEU) do not occur in nature, they must be manufactured. However, these materials are also manufactured for civilian uses in nuclear energy. In addition to closely monitoring the thousands of nuclear weapons around the planet, there is an ongoing need to ensure proper security of tons of these radiological materials across dozens of nations with nuclear power initiatives. It is a challenging task but is absolutely essential to ensuring the nuclear safety of the international community.

The last barrier against the illicit use of radiological material is physical security and controls. In recent years, nations around the world have enhanced security measures to include detection of radiological materials, especially in ports where large quantities could potentially be transferred (Fig. 15-10). There are also human portals at nuclear facilities able to detect workers with radioactive materials.

In recent years, there have been a variety of new developments in stand-off detectors. Detectors are positioned at major events with national or international security interests such as the Olympic Games or major political events. These devices are sensitive enough to detect individuals walking by who are undergoing diagnosis or treatment with radiopharmaceutical drugs and could certainly detect the presence of an individual carrying a nuclear or radiological device.

FIGURE 15-10 Radiation portal monitor (RPM) at the border crossing in Port Huron, Michigan. Photo by Jarek Tuszynski.

The future of this emerging technology looks promising. Radiation detector applications are now available for Apple and Android devices. Smartphone cameras utilize a small silicon-based chip to detect visible light. The chip is a highly sensitive, complementary metal-oxide-semiconductor (CMOS). In addition to detecting wavelengths of visible light, the CMOS detects higher wavelengths, including gamma radiation and X-rays (ANSTO, 2014).

Immediate Actions

There are a number of nuclear and radiological response scenarios, ranging from a single individual receiving a workplace exposure to a nuclear detonation or nuclear power facility emergency with global implications. Each scenario poses unique challenges and requires multi-agency coordination, planning, training, and exercise efforts in order to adequately prepare. There are five broad scenarios that should be considered:

1. A transportation or occupational accident involving radiological materials. Consider the possibility of dozens of injured or exposed people on the scene and determine who will make the final decisions and what guidelines will be used to inform the decision-making process.
2. An accident at a nuclear facility with dozens initially injured and potentially exposed to excessive radiation, which could lead to ARS, and thousands more potentially exposed in the immediate area and downwind. Messages should be preplanned in what information needs to be communicated under various circumstances and plans should be in place to manage mass prophylaxis and/or evacuations. Everyone at risk must be registered in a database for appropriate follow-up.
3. An RDD or dirty bomb with the explosion of a package or a vehicle carrying radioactive materials. Consider the management of the scene where there may be dozens of individuals with traumatic injuries. Although the risk of ARS is unlikely, consider how the long-term health risks will be managed in the exposed population. The scene must be characterized and secured. The exposed must be decontaminated and registered for follow-up.
4. A nonexplosive RDD where radiological material is dispersed by mechanical means without drawing the attention of an explosion. A radiological exposure device (RED) is also possible by placing a highly radioactive substance near crowded places such as a subway. Passersby can unknowingly receive significant doses of radiation.
5. A nuclear detonation could destroy an entire city but a small IND could appear more like the September 11, 2001, attacks on the United States with a block or several blocks of buildings as "Ground Zero." The challenges will include large amounts of radioactive debris, many traumatic injuries complicated by many more cases of ARS, and chronic exposures for many miles downwind of the detonation.

The good news is that responding to nuclear and radiological incidents is more predictable than many other attack and accident scenarios. Some biological and chemical incident scenarios have such an array of unknown variables, the ability to rapidly detect and characterize the threat is difficult and time-consuming. With radiological events, the principles are

well understood and there are fewer unknowns. The detection instrumentation is ubiquitous, dependable, and quick to use. The ability to predict those at risk and offer recommendations, such as evacuation or sheltering in place, is much more straightforward than other threats. Decades of advancements in nuclear power facility preparedness, nuclear weapons testing, and Cold War preparedness initiatives have established a robust body of nuclear preparedness guidance and information.

Public Health and Protective Actions

The primary roles of public health agencies in the aftermath of a nuclear or radiological incident are to assess public health risks, develop recommendations to optimize protection of public health, manage the medical needs, and communicate recommendations to protect the public. The public health response to international nuclear and radiological emergencies is led by a close collaboration between World Health Organization (WHO) and the International Atomic Energy Agency (IAEA). During a response, the WHO brings a wide range of multinational, multidisciplinary experts together through the Radiation Emergency Medical Preparedness and Assistance Network (REMPAN). The network includes dozens of radiation scientists, researchers, and healthcare professionals (REMPAN, 2014) who support all aspects of the public health response.

International agencies involved in nuclear or radiological incident response include:

- International Atomic Energy Agency (IAEA)
- World Health Organization (WHO)
- Nuclear Energy Agency (NEA)
- Food and Agricultural Organization (FAO)
- Organization on Economic Cooperation and Development (OECD)
- United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA)
- World Meteorological Organization (WMO)

In the United States, the Environmental Protection Agency (EPA) established radiological emergency safety standards for workers and for the general public. Development began with planning for response to nuclear power facility accidents called Protective Action Guides (PAGs). The most recent EPA PAGs for nuclear incidents were published in 1992 (EPA, 1992). However, following the terrorist attacks of 2001, a series of national exercises were conducted to identify gaps and opportunities to improve the federal response to a variety of scenarios. It was discovered through these exercises, the changing nature of nuclear and radiological threats, and information emerging from the Chernobyl disaster, that the existing guides were insufficient.

Protective Action Guides specifically for RDD and IND incidents were issued by the Department of Homeland Security in 2006. The PAGs include recommendations for the general public and separate recommendations for first responders. The triggers used for

Table 15-3 Response Worker Protective Action Guidelines (DHS, 2006) [a,b]

Total effective date equivalent (TEDE) guideline	Activity	Condition
5 rem (50 mSv)	All occupational exposures	All reasonably achievable actions taken to minimize dose
10 rem (100 mSv)	Protecting valuable property necessary for public welfare (eg, a power plant).	Exceeding 5 rem unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.
25 rem (250 mSv)	Lifesaving or protection of large populations	Exceeding 5 rem unavoidable and all appropriate actions taken to reduce dose. Monitoring available to project or measure dose.

[a]For potential dose >10 rem, special medical monitoring programs should be employed, and exposure should be tracked in terms of the unit of absorbed dose (rad) or gray (Gy) rather than TEDE (rem) or millisievert (mSv).
[b]In the case of a very large incident such as an IND, incident commanders may need to consider raising the property and lifesaving response worker guidelines to prevent further loss of life and massive spread of destruction.

deciding when to shelter or evacuate populations at risk are all based on the PAGs. For example, during a nuclear or radiological incident, when first responders are balancing their moral obligations to protect the public against their personal risks, it is not a time to begin the development of a framework to facilitate a rational decision-making process. This decision-making process is done with the PAGs. Table 15-3 summarizes the suggested maximum dose for response workers under various conditions (DHS, 2006). Incident commanders must also keep fundamental safety practices in mind. This includes consideration of the three most important factors: time, distance, and shielding. Workers should be rotated to minimize time spent in the contaminated area. A safe distance should be maintained and shielding from the source should be instituted to the greatest extent possible. Appropriate personal protective equipment should be tailored for the event and use of prophylactic medications must be considered to reduce exposures and retention times of isotopes (Fig. 15-11). Using the control measures, most RDD incidents can be managed keeping first responders below an occupational exposure 5 rem (50 mSv). In high radiation areas with victims awaiting rescue, the incident commander and responders must understand and accept the risk of their actions before entering the area.

There are also recommended initial actions for the general public for the time prior to the availability of radiological measurements and associated protective action guidance. If there is a suspicious explosion or if local authorities announce the possibility of a radiological release, individuals in the area should be instructed to cover their nose and mouth with a piece of cloth and take immediate cover inside the nearest building. Those taking shelter inside buildings should ensure the doors and windows are closed and the heating, ventilation, and air conditioning system is shut down. If an announcement is made to evacuate an area with individuals sheltered, they should be instructed again to cover their nose and mouth and evacuate to another building at a safe distance. Those who may have

FIGURE 15-11 Emergency response personnel check for radiological activity on a manikin at a Federal Emergency Management Agency (FEMA) training facility. *Photograph by Benjamin Crossley courtesy of the FEMA.*

been exposed to radioactive particles need to remove contaminated clothing as soon as possible. The biggest problem facing those in the immediate area of a suspicious blast or release is panic. In this time of calamity and confusion, the local authorities will have the responsibility to maintain calm and remind the public of basic principles. For example, limiting exposure to radiation is simply a matter of time, distance, and shielding.

Basics of Nuclear and Radiological Protection

In order to decrease exposure:

Time: Limit the time spent in the area.
Distance: Increase the distance between yourself and the blast or release site.
Shielding: Place more material and higher density material between yourself and a radioactive source (eg, if inside a building, interior rooms or basements offer the best protection).

Medical Response

According to the Centers for Disease Control and Prevention, there are six areas to be considered by healthcare organizations as they prepare for nuclear and radiological incidents. These areas include notification and communication, triage, patient management, healthcare worker protection, surveillance, and community planning (CDC, 2003).

Notification and communication include an understanding of existing plans and procedures, how each organization fits into the incident command structure, and where to find the expertise needed to answer detailed clinical and technical questions. It is essential that consistent internal and external communications are established, especially with the media. Public confidence in the health and medical response has far reaching ramifications. The fastest way to undermine and lose the public's trust is through inconsistent messages and actions.

Triage needs to be planned in advance and practiced through exercises. The key to successful triage is the understanding of the proper assumptions and correct processes. Many injured and exposed individuals will triage and transport themselves. The patient surge and triage process is managed best by establishing a separate assessment or triage area away from the emergency department. Patient surge will occur on top of the typical demand for services and may include burns, trauma, external contamination in need of decontamination, and internal contamination in need of the rapid administration of radiological pharmaceuticals.

Successful patient management following a radiological incident will depend on preevent planning and exercises (Fig. 15-12). Planning includes the organization of the physical layout with clear signage to direct and manage a large influx of people seeking care. A multistep process is needed including an initial triage, decontamination process, treatment of injuries, identification and treatment of ARS, management of clinical specimens, and appropriate referral of those with special needs, such as pregnant women and those needing mental health services.

Healthcare provider protection begins prior to an event. Personal protective equipment is essential for those in contact with potentially contaminated patients and an ample supply should be maintained at all times. Training will also play a key role in healthcare worker

FIGURE 15-12 Emergency response personnel check for radiological activity on a manikin at the Noble Training Facility. *Photograph by Benjamin Crossley courtesy of FEMA.*

protection. Not all employees need to receive the same training, although they all should have an awareness level of nuclear and radiological threats to gain an understanding of what the possible scenarios include. Some will need more detailed training on decontamination, use of detection equipment, and detailed implementation of the response plan. Practice through exercises is essential to reinforce training and to identify gaps in planning.

Surveillance is simply the collection and analysis of information on those seeking care after an incident. This is essential in the first hours and days following an incident to inform the decision-making on initial action and treatment recommendations. In the long term, it is important for follow-up activities, additional treatment suggestions, and long-term study of the health outcomes so lessons learned can be applied toward future events. The minimal information needed includes patient contact information, demographics, location at the time of the incident, and initial actions taken.

Community planning is not about the final planning document. It is about relationships in the context of disaster scenarios. Healthcare organizations must cultivate the relationships needed to facilitate timely delivery of resources needed during a radiological disaster. These resources include additional supplies, equipment, staffing, and pharmaceuticals. The plan is not worth the paper it is written on, if it is not a reflection of the relationships built during the planning process.

Medical Countermeasures

In the United States, when local medical infrastructure is overwhelmed by a nuclear or radiological incident, they should notify their local public health agency who can request support through the state. If the state cannot meet the needs, they will request federal support. Federal support may include deployment of medical countermeasures from the Strategic National Stockpile (SNS). Many preparedness planners and responders quickly think of the stockpile as a source of pharmaceuticals for mass prophylaxis following a bioterrorism attack or as the Chempack program, which places nerve agent antidote in communities across the nation. Some are not as aware of the SNS resources available to support a radiological incident response.

The SNS has a variety of critical radiological pharmaceutical resources. (HHS, 2008) Resources include:

- Chelating agents
- Calcium diethylenetriamene pentaacetate
- Zinc diethylenetriamene pentaacetate

These agents can be used to treat internal contamination by transuranic heavy metals including plutonium, americium, and curium.

- Prussian blue to treat internal contamination of cesium and thallium
- Potassium iodide to treat internal contamination of radioactive iodine (I-131)
- Growth factors/cytokines for white blood cells to aid in the recovery of suppressed bone marrow

In most cases, these drugs need to be administered as quickly as possible and some require an "Emergency Use Authorization" from the Food and Drug Administration. Preplanning these scenarios in detail is essential.

Recovery

The long-term issues associated with a nuclear or radiological incident can be far worse than the short-term impact. The persistent nature of many radiological sources could result in the need to abandon a large affected area for years. Consider the devastation of Hurricane Katrina and the slow recovery of New Orleans. Many evacuated residents have chosen to never return and the city will never be the same. In the case of Hurricane Katrina, the people have a choice. In the case of a dirty bomb or other persistent radiological hazard, there may be no choice. A large area, even of the downtown district in a major city, could become uninhabitable for years following a dirty bomb or other radiological release.

This was certainly on the minds of the DHS interagency work group developing clean-up guidelines in 2006. Again, this was a change associated with the PAGs. The problem is there are so many potential scenarios with such a broad range of outcomes it makes it difficult to establish numerical standards. The guidelines instead refer to a variety of other sources and leave the decision to local, state, and federal responders to decide actions on a case by case basis. While this sounds like a reasonable approach, the International Commission on Radiation Protection is among those considered as providing acceptable guidance. They have supported a long-term, acceptable clean-up standard of 10,000 mrem per year. That is 30 times more than an average person receives from all natural and man-made sources each year (ANSI, 2006). Mainstream media quickly and irrationally compared it to 1600 chest X-rays, the current Nuclear Regulatory Commission public exposure limit of 100 mrem, and the estimated cancer rate of one in every four people who are exposed to that level (Hebert, 2006). If this was the media response to a recommendation defaulting to other sources of expertise generally regarded as competent to make the recommendations, what will the media and public response be when actual names and faces are associated with an abandoned area? With ongoing questions concerning "how clean is clean," there is a high likelihood the long-term impact of a dirty bomb or other dispersion of a persistent radiological threat is going to make the affected area uninhabitable for an extended period of time. This may or may not be due to actual health threats.

While the environmental impact is being debated, the human health impact will be a source of ongoing controversy as well. Those exposed and many more who never were but are still concerned (the "worried well") will suffer the psychological stress associated with the possibility of a looming terminal diagnosis. As with Chernobyl, there will be individuals for years to come placing the responsibility for a variety of health conditions on the incident. While some will have legitimate claims, it is unfortunate many who do may be lost in the noise of those whose claims are not legitimate. Should this scenario occur, it will be an ongoing challenge for years, and possibly for generations. The only way to minimize the chronic social impact is to manage it well from the moment it occurs, including the registration and close monitoring of those truly at risk.

Summary

The threat of a nuclear or radiological disaster is real and growing. As technology continues to move forward, more dangerous information and materials are likely to become available to rogue nations and terrorists. Although most nuclear and radiological preparedness is based on transportation accident and nuclear facility accident scenarios, in recent years many initiatives have begun addressing the unique aspects of intentional nuclear or radiological attack. Many nations have established a preparedness foundation for these threats through military and industrial experience with radiological materials. However, much work remains in developing the tools needed for effective management of these incidents in the future.

While nuclear and radiological principles are well understood, gaps exist in public health and medical preparedness and response. First responders can respond and characterize the threats but managing human exposures is still wrought with questions. New treatment approaches and pharmaceuticals are needed to effectively care for exposed individuals. More training and better mass care approaches are needed in healthcare. Public health needs more effective processes to identify and track those exposed and also needs key environmental health questions answered so they can confidently chart a course for managing the local public health threats that may persist.

Websites

American College of Radiology. www.acr.org/.

Armed Forces Radiobiology Research Institute. https://www.usuhs.edu/afrri.

Centers for Disease Control and Prevention, Radiation Emergencies. www.bt.cdc.gov/radiation/.

Centers for Disease Control and Prevention, Medical Countermeasures (Treatments) for Radiation Exposure and Contamination. http://emergency.cdc.gov/radiation/countermeasures.asp.

Department of Energy. www.energy.gov/.

Department of Health and Human Services, Radiation Event Medical Management. www.remm.nlm.gov/.

Environmental Protection Agency, Protective Action Guidelines. www.epa.gov/radiation/rert/pags.html.

Environmental Protection Agency, Radiation Protection. www.epa.gov/radiation/index.html.

Food and Drug Administration, Emergency Use Authorization of Medical Products. http://www.fda.gov/RegulatoryInformation/Guidances/ucm125127.

Food and Drug Administration, Radiological Health Program. http://www.fda.gov/radiation-emitting-products/fdaradiologicalhealthprogram/default.htm.

Health Physics Society. www.hps.org/.

International Atomic Energy Agency. www.iaea.org/.

National Nuclear Security Administration, Federal Radiological Monitoring and Assessment Center. http://www.nnsa.energy.gov/aboutus/ourprograms/emergencyoperationscounterterrorism/respondingtoemergencies-0-1.

Nuclear Regulatory Commission, Emergency Preparedness. www.nrc.gov/about-nrc/emerg-preparedness.html.

Nuclear Regulatory Commission, Radiation Basics. www.nrc.gov/about-nrc/radiation/health-effects/radiation-basics.html.

Oak Ridge Institute, Radiation Emergency Assistance Center/Training Site. www.orise.orau.gov/reacts/.

Oak Ridge Institute, Managing Radiation Emergencies, Guidance for Hospital Medical Management. https://orise.orau.gov/reacts/guide/care.htm.

United States Nuclear Regulatory Commission (USNRC), 2014. History. Available at: http://www.nrc.gov/about-nrc/emerg-preparedness/history.html.

U.S. National Response Team. www.nrt.org/.

World Health Organization, Radiation Emergencies. http://www.who.int/ionizing_radiation/a_e/en/.

World Health Organization, WHO's Role in Radiation Accidents and Emergencies. http://www.who.int/ionizing_radiation/a_e/role/en/.

References

American National Standards Institute (ANSI), January 4, 2006. Critics Call DHS Dirty Bomb Cleanup Guidelines Too Weak. ANSI News and Publications. Available at: www.ansi.org/news_publications/news_story.aspx?menuid=7&articleid=1116.

Arms Control Association, October 2007. Nuclear Weapons: Who Has what at a Glance. Strategic Arms Control Policy Fact Sheet. Available at: www.armscontrol.org/factsheets/Nuclearweaponswhohaswhat.

Australian Nuclear Science and Technology Organisation (ANSTO), June 30, 2014. Smartphone Radiation Detector App Tests Positive. Available at: http://phys.org/news/2014-06-smartphone-detector-app-positive.html.

Cardis, E., Howe, G., Ron, E., Bebeshko, V., Bogdanova, T., Bouville, A., et al., June 2006. Cancer consequences of the Chernobyl accident: 20 years on. J. Radiol. Prot. 26 (2), 127–140. Epub 2006 Apr 24.

Cardis, E., 2005. Cancer effects of radiation exposure from the Chernobyl accident. In: International Conference: Chernobyl – Looking Back to Go Forwards towards a United Nations Consensus on the Effects of the Accident and the Future, Vienna, 6–7 September, 2005. International Atomic Energy Agency. Available at: http://www-ns.iaea.org/meetings/rw-summaries/chernobyl-conference-2005.asp?s=10&l=80#1.

Centers for Disease Control and Prevention (CDC), December 2003. Interim Guidelines for Hospital Response to Mass Casualties from a Radiological Incident. Available at: www.bt.cdc.gov/radiation/pdf/MassCasualtiesGuidelines.pdf.

Centers for Disease Control and Prevention (CDC), March 18, 2005a. Acute Radiation Syndrome. A Fact Sheet for Physicians. Available at: www.bt.cdc.gov/radiation/pdf/arsphysicianfactsheet.pdf.

Centers for Disease Control and Prevention (CDC), June 29, 2005b. Cutaneous Radiation Injury. A Fact Sheet for Physicians. Available at: www.bt.cdc.gov/radiation/pdf/criphysicianfactsheet.pdf.

Centers for Disease Control and Prevention (CDC), March 23, 2005c. Prenatal Radiation Exposure. A Fact Sheet for Physicians. Available at: www.bt.cdc.gov/radiation/pdf/prenatalphysician.pdf.

Department of Homeland Security, 2006. Protective action guides for radiological dispersal device (RDD) and improvised nuclear device (IND) incidents. Fed. Regist. 71 (1), 174–196. Available at: http://hps.org/govtrelations/documents/dhs_pags_fr.pdf.

Environmental Protection Agency (EPA), 1992. Protective Action Guides (PAGs). Available at: http://www.epa.gov/radiation/rert/pags.html.

Figley, M.M., 1980. Introduction of SI units. Am. J. Roentgenol. 134 (1), 208.

Health Physics Society (HPS), 2010. Radiation Exposure from Medical Exams and Procedures: Fact Sheet. Adopted January 2010. Available at: http://hps.org/documents/Medical_Exposures_Fact_Sheet.pdf.

Hebert, H.J., January 4, 2006. Government Has Dirty Bomb Cleanup Guide. San Francisco Chronicle.

International Atomic Energy Agency (IAEA), 2005. Chernobyl's 700,000 "Liquidators" Struggle with Psychological and Social Consequences. Staff Report. August 2005.

Jaworowski, Z., Winter 2000–2001. The truth about Chernobyl is told. 21st Century Science and Technology Magazine. Available at: www.21stcenturysciencetech.com/articles/chernobyl.html.

Library of Congress (LOC), January 1996. Revelations from the Russian Archives. Available at: www.loc.gov/exhibits/archives/cher.html.

Moysich, K.B., Menezes, R.J., Michalek, A.M., 2002. Chernobyl-related ionising radiation exposure and cancer risk: an epidemiological review. Lancet Oncol. 3 (5), 269–279.

Patterson, W.C., 1986. Chernobyl: worst but not first. Bull. Sci. 42, 43–45.

Radiation Emergency Medical Preparedness and Assistance Network (REMPAN), 2014. Collaborating Centres and Liaison Institutions. Available at: http://www.who.int/ionizing_radiation/a_e/rempan/en/.

Shukman, D., March 18, 2015. Chernobyl: Containing the World's Worst Nuclear Accident. BBC News. Available at: http://www.bbc.com/news/science-environment-31939778.

United Nations (UN), 1988a. Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation. 1988 report to the General Assembly, with annexes, Appendix: acute radiation effects of victims of the Chernobyl nuclear power plant accident. United Nations, United Nations Publication, Sales Publication E.88.IX.7. United Nations, New York. Available at: http://www.unscear.org/docs/reports/1988/1988r_unscear.pdf.

United Nations (UN), 1988b. Sources, Effects and Risks of Ionizing Radiation: United Nations Scientific Committee on the Effects of Atomic Radiation. 1988 report to the General Assembly, with annexes, Annex D: exposures from the Chernobyl accident. United Nations, United Nations Publication, Sales Publication E.88.IX.7 United Nations, New York. Available at: www.unscear.org/docs/reports/1988/1988i_unscear.pdf.

United Nations Office for Disarmament Affairs, 1968. Multilateral Arms Regulation and Disarmament Agreements, Treaty on the Non-proliferation of Nuclear Weapons. Available at: http://disarmament.un.org/TreatyStatus.nsf/.

United States Nuclear Regulatory Commission (USNRC), April 2006. Backgrounder on Chernobyl Nuclear Power Plant Accident. Available at: www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.pdf.

U.S. Department of Health and Human Services (HHS), 2008. Radiation Event Medical Management. Strategic National Stockpile. Available at: www.remm.nlm.gov/sns.htm.

United States Nuclear Regulatory Commission (USNRC), 2013. Backgrounder on Chernobyl Nuclear Power Plant Accident. Available at: http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.html.

16

Pandemic Influenza

OBJECTIVES

- Differentiate between seasonal and pandemic influenza.
- Identify proteins that change during genetic mutation of influenza viruses.
- Describe pharmaceutical options available to prevent influenza or reduce severity of disease.
- List the World Health Organization (WHO) phases of pandemic response.
- Explain the difference between the WHO pandemic phases and the US pandemic intervals.
- Describe how an outbreak peak curve can be compressed and what benefits are derived from compressing it.
- List what individuals can do to reduce the risk of influenza.
- Define nonpharmaceutical interventions and give examples.
- Summarize the types of activities local public health agencies should consider for each of the US pandemic intervals.
- Describe the limitations of a government response to a pandemic.

Introduction: The 1918 Influenza Pandemic and the Wickstrom Family

They were a young, adventurous, and hardworking couple with big plans ahead. Simon Wickstrom was 21 years old when he married Selma who was just 16. Simon had emigrated from Sweden to Minnesota, and in 1898 he built a farmhouse there for his new bride, not long before Selma gave birth to their first child, Ella. She was just 17 when their first child arrived. Many more children followed. Seven more arrived in the coming years, including Ralph, Lester, Carrie, Ted, Florence, Elmer, and Alvin (Fig. 16-1). It was a hard life filled with long days of difficult work. As their family grew, Selma had her older children, Ella and Ralph, to help with the chores.

November 1918 should have been a time for joyful celebration for families like the Wickstroms. The holidays were approaching and with the signing of the armistice ending World War I, peace was on the horizon. Though the "Great War" was ending, a new battle was emerging. It would eventually kill far more people than any war in history. The influenza pandemic of 1918–1919 became the worst influenza outbreak in modern history, infecting about one-third of the global population (Burnet and Clark, 1942; Frost, 1920). The case–fatality rate for most influenza pandemics is generally less than 0.1%. However, the 1918 influenza strain had case–fatality rates estimated to be greater than 2.5% (Marks and Beatty, 1976; Rosenau and Last, 1980). As a result, the global death estimates from this pandemic are about 50 million (Johnson and Mueller, 2002).

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FIGURE 16-1 Simon and Selma Wickstrom family (CDC, 2006a).

The influenza pandemic reached across every continent and caused devastating illnesses even in the most remote regions. The Wickstrom family of rural Minnesota was no exception. The infection swept through the family, sickening the parents and all eight children. Those who were less ill cared for the others. The eldest daughter, 19-year-old Ella, took care of her father and the other children, while her mother Selma and one of her brothers maintained the farm. In late November, 13-year-old Lester died, followed 5 days later by his 40-year-old father, Simon. The children were given little time to say goodbye to their brother and father. Their bodies were placed in wooden coffins and hastily buried by the local undertaker. Selma became a single mother at the age of 36. She and the surviving children, ranging in age from 1 to 19 years, were left to carry on in that chilling Minnesota winter (CDC, 2006a). These kinds of losses played out millions of times around the world in 1918 and 1919 and left countless legacies of suffering and courage, the depth and breadth of which will never be fully known.

Pandemic Definitions

Antibiotic (also antimicrobial) Drug developed from fungi, molds, and certain soil bacteria that destroys or prevents the growth of other disease-causing bacteria.

Antigenic drift Process in which the influenza virus undergoes normal genetic mutations. The amount of change can be subtle or dramatic, but eventually as drift occurs, a new variant strain becomes dominant. This process allows influenza viruses to change and reinfect people repeatedly through their lifetime and is the reason influenza virus strains in vaccine must be updated each year.

Antigenic shift Process in which the existing H (hemagglutinin) and N (neuraminidase) are replaced by significantly different H and Ns. These new H or H/N combinations are perceived by human immune systems as new, so most individuals do not have preexisting antibody protection to novel viral strains. This is one of the reasons pandemic viruses can have such a severe impact on the health of populations.

Antiviral Drug used to prevent or cure a disease caused by a virus by interfering with the ability of the virus to multiply or spread from cell to cell.

Asymptomatic Infected but presenting no symptoms of disease.

Avian influenza (also AI or bird flu) A highly contagious viral disease with up to 100% mortality in domestic fowl caused by influenza A virus subtypes H5 and H7 (see Hemagglutinin). Low-pathogenic AI causes few problems and is carried by many birds with no resulting problems. Highly pathogenic AI kills birds and if transmitted to humans, can also be fatal. There is little or no human immunity, however humans are rarely affected.

Community-based measures Activities to increase social distance that may include measures applied to whole neighborhoods, towns, or cities (eg, snow days, establishment of clinics, and community-wide quarantine).

Containment measures Measures taken to control disease exposure at specific sites or buildings that may include cancellation of public events (eg, concerts, sports events, and movies), closure of office buildings, apartment complexes, or schools, and closure of public transit systems. These measures can also involve restricting entrance to buildings or other sites (eg, requiring fever screening or use of face masks before entry).

Epidemic Disease occurring suddenly in humans in a community, region, or country in numbers clearly in excess of a typical presentation of the disease.

H5N1 Variant of avian influenza, which is a type of influenza virulent in birds. H5N1 was first identified in Italy in the early 1900s and is now known to exist worldwide. Both low and highly pathogenic variants exist in different regions of the world.

Hemagglutinin Important surface structure protein of the influenza virus. Hemagglutinin is an essential gene for the spread of the virus throughout the respiratory tract that enables the virus to attach itself to a cell in the respiratory system and penetrate it. Hemagglutinin is referred to as the "H" in influenza viruses (eg, H1N1). See also "Neuraminidase."

HPAI Highly pathogenic form of avian influenza. Avian flu viruses are classified based upon the severity of the illness and HPAI is extremely infectious among humans. The rapid spread of HPAI, with outbreaks occurring at the same time, is of growing concern for human health as well as for animal health. See also "LPAI."

Influenza Serious viral disease caused by influenza viruses that infect the respiratory tract.

Isolation State of physical separation and restriction of movement between persons or groups to prevent the spread of disease. Isolation measures can be undertaken in hospitals or homes, as well as in alternative facilities.

LPAI Low pathogenic form of avian influenza. Most avian flu strains are classified as LPAI and typically cause little to no clinical signs in infected birds. However, some LPAI virus strains are capable of mutating under field conditions into HPAI viruses. See HPAI.

Mutation Any alteration in a gene from its original natural state. This change may be disease causing or a benign, normal variant.

Neuraminidase Important surface structure protein of the influenza virus. Neuraminidase is an essential enzyme for the spread of the virus throughout the respiratory tract that enables the virus to escape the host cell and infect new cells. Neuraminidase is referred to as the "N" in influenza viruses (eg, H1N1). See also "Hemagglutinin."

Pandemic Worldwide outbreak of a disease in humans with case numbers clearly in excess of normal.

Pathogenic Causing or capable of causing disease.

Prepandemic vaccine Vaccine created to protect against currently circulating H5N1 avian influenza virus strains with the expectation it would provide at least some protection against new virus strains that might evolve.

Prophylactic Pharmaceutical or a procedure with properties capable of prevention or protection against a disease or condition (eg, vaccines, antibiotics).

Quarantine Time period of physical separation or restriction of movement decreed to control the spread of disease. Before the era of antibiotics, quarantine was one of the few available means of halting the spread of infectious disease. Quarantine is still used today as needed. Individuals may be quarantined at home or in designated facilities.

Seasonal flu Respiratory illness caused by the influenza virus transmitted from person to person. Most individuals have some immunity, and a vaccine is available. Seasonal flu is also known as the common flu or winter flu.

Virus One of the many simple, submicroscopic infectious agents of plants, animals, and bacteria that causes disease. Viruses consist essentially of a core of RNA or DNA surrounded by a protein coat. Unable to replicate without a host cell, viruses are typically not considered living organisms.

Widespread or community-wide quarantine Refers to the closing of community borders or the erection of a real or virtual barrier around a geographic area (a cordon sanitaire) with prohibition of travel into or out of the area.

Pandemic Influenza

Influenza, referred to as the flu, is a highly infectious respiratory disease caused by the influenza virus. It is a segmented, single-stranded, RNA virus that is part of the Orthomyxoviridae family (Fig. 16-2). The name influenza comes from the Italian form of the Latin word "influentia" as influenza illnesses were believed to result from occult "influences." The Orthomyxoviridae family name is derived from the Greek words "orthos," or straight, and "myxo," or mucus (International Committee on Taxonomy of Viruses, 2006). The name of a specific influenza strain is usually based on where it is initially discovered such as references to the geographic location (Hong Kong flu) or animal reservoir (bird flu).

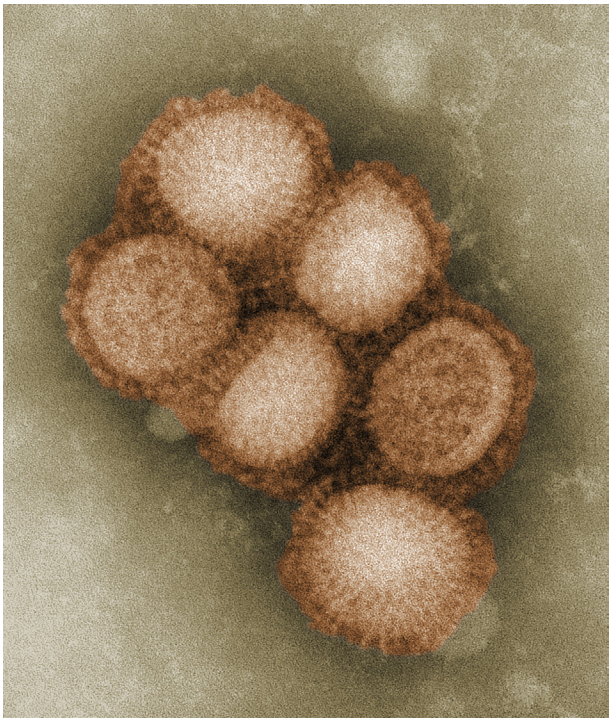

FIGURE 16-2 Negative-stained transmission electron micrograph depicts the ultrastructural details of a number of influenza virus particles, or "virions." *Centers for Disease Control and Prevention (CDC) Photograph by Cynthia Goldsmith.*

Human influenza viruses have their origin in animal reservoirs that adapt and pass from birds and swine directly or through other mammals. To cause a pandemic, three barriers must be overcome: the virus must be transmissible from animals to humans, the virus must be able to infect human cells, and there must be the ability to transmit the virus from human to humans. While these seem like formidable barriers, evidence of the many pandemics indicates these genetic changes are achievable if not common.

Influenza pandemics occur when a dramatic reassortment of the genetic structure of the virus makes it unrecognizable to the human immune system. Throughout the past century there were four pandemics: 1918, 1957, 1968, and 2009 (Cox and Subbarao, 2000). The severity of seasonal or pandemic influenza is caused by the genetic structure of the virus. There are three types of influenza viruses: A, B, and C. Influenza A is the most dangerous for humans and influenza C is the least dangerous. The specific structure of the influenza virus is expressed by the proteins it carries. Hemagglutinin proteins of the virus are the components that enable the virus to penetrate a foreign body. There are 16 different hemagglutinin proteins possible. Neuraminidase is another key protein of the virus. Neuraminidase has nine protein varieties. These two proteins are the defining factors for each strain of influenza and are the basis for the "H_N_" designation. For example, there have been concerns over H5N1 as a potential candidate for a future influenza pandemic. Another terminology used in discussing the various strains of viruses refers to the pathogenicity in animals. Influenza virus strains are referred to as being either low pathogenic or high pathogenic. For several years, a low-pathogenic avian influenza (LPAI) H5N1 strain has been present in North America, while there has been a highly pathogenic avian influenza (HPAI) H5N1 strain present in Asia (Badae et al., 2013; Inamasu et al., 2012; Manning, 2006).

Changes in a virus are caused by two types of mutations. Antigenic drift is a constant process of genetic change naturally occurring as a virus replicates itself. Small imperfections happen as copies are made causing a genetic drift, or slow process of change to occur. Occasionally, an antigenic shift occurs. This is a dramatic reassortment of the genetic structure of the virus when it is combined with other influenza strains and exchanges genetic material (Webster and Govorkova, 2006). Antigenic shift usually occurs in animals such as swine as they carry both human and animal strains of influenza virus and provide an ideal reservoir for various strains to mix and shift their genetic structure Reperant, et al., 2012.

Human Health Effects

Influenza symptoms typically include fever, muscle pain, runny nose, and cough. Those who die from seasonal influenza frequently have chronic medical conditions or weaker immune systems and die from secondary illnesses such as pneumonia. The primary differences during an influenza pandemic are the disease severity and the populations affected (see Table 16-1). Not only will the case–fatality ratio be excessive during a pandemic, but often those most severely affected are different demographically. In the 2009–2010 influenza A H1N1 pandemic, a study of 100 deaths revealed a high incidence of viral

Table 16-1 Differences Between Seasonal and Pandemic Influenza

Seasonal Influenza	Pandemic Influenza
Annual occurrence	Rare occurrence (several times per century)
Some natural human immunity	Little or no human immunity
Weak immune systems at increased risk	Those at increased risk have a strong immune system
Vaccine available before flu season	Vaccine not available for several months
Adequate antivirals for those at increased risk	Inadequate supply of antivirals for those at risk
Healthcare system is adequate to provide care	Healthcare system overwhelmed
Mild, non–life-threatening illness in most people	Severe, life-threatening illness in many more
Annual U.S. deaths in the tens of thousands	U.S. deaths in the hundreds of thousands
Does not normally close schools	School closures likely
Does not cause travel restrictions among the healthy	Travel restrictions likely
Mild impact on the economy and business continuity	Severe impact on the economy and business continuity

Adapted from the U.S. Department of Health and Human Services: www.pandemicflu.gov.

pneumonia and diffuse alveolar damage. These findings were similar to other findings in influenza outbreaks but different than "typical" seasonal influenza deaths (Sheih et al., 2010). There were also a higher incidence of deaths in patients with morbid obesity, pregnancy, and sleep apnea. Rather than populations with weaker immune systems having more severe illness, those with healthier immune systems can be more susceptible. When the human immune system is fighting an infection, cytokines are responsible for activating the immune functions and also stimulating production of more cytokines. It is a looped system that keeps the immune system balanced to fight illness effectively while minimizing damage to healthy cells. Some highly pathogenic strains of influenza produce a "cytokine storm" where cytokines and immune cells become hyperstimulated and damage the healthy cells of an infected respiratory tract. During the 1918 pandemic, many individuals between the ages of 18 and 40 with healthier immune systems had more severe illness due to cytokine stimulation. As the immune system began damaging the healthy cells of the respiratory tract, it led to acute respiratory distress syndrome (ARDS) (Kobasa et al., 2004; Osterholm, 2005). ARDS killed many within several days. Others succumbed over a longer period of time due to secondary bacterial infections of the lungs. These infections were ushered in by viral damage to the epithelial cells of the respiratory tract. Although the epithelial cells usually sweep the respiratory tract clean, as they are damaged by influenza viruses, bacteria from the mouth can make their way down the respiratory tract and cause secondary illnesses.

Because influenza is caused by a virus, there are only two pharmaceutical options. A vaccine can be used to prevent or reduce the severity of influenza (Figs. 16-3–16-6). Antiviral drugs can be used to reduce the severity and length of the illness. Antiviral drugs are often the initial focus of pandemic preparedness and response efforts because vaccine production requires access to the specific pathogenic organism FDA, 2008. Influenza viruses quickly mutate, making them evasive targets for vaccine development. Despite these historical limitations, a prepandemic H5N1 vaccine has been approved and is being

FIGURE 16-3 A single prefilled Fluzone® intradermal influenza virus vaccine syringe. *Centers for Disease Control and Prevention (CDC) photograph by Douglas Jordan, M.A.*

stockpiled. It is not known if the vaccine will offer enough protection or if a future H5N1 mutation could make the vaccine ineffective.

> *You might be asking too much if you're looking for one vaccine for every conceivable influenza. If you have one or two that cover the vast majority of isolates, I would not be ashamed to call that a universal vaccine.*
>
> *Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases (NIAID) in Bethesda, Maryland (Talkington, 2009).*

If the current influenza vaccine production capacity is used to quickly make a new vaccine from a newly discovered influenza strain, the global influenza vaccine production capacity is about 500 million doses per year. The first shipments of vaccine to leave those facilities would take several months to develop. Some vaccine is cultured in eggs using a time-consuming process (Morse et al., 2006). This production schedule cannot be changed

FIGURE 16-4 A 5-ml vial containing the influenza virus vaccine, Fluzone®, distributed by Aventis Pasteur, USA. *Centers for Disease Control and Prevention (CDC) photograph by James Gathany.*

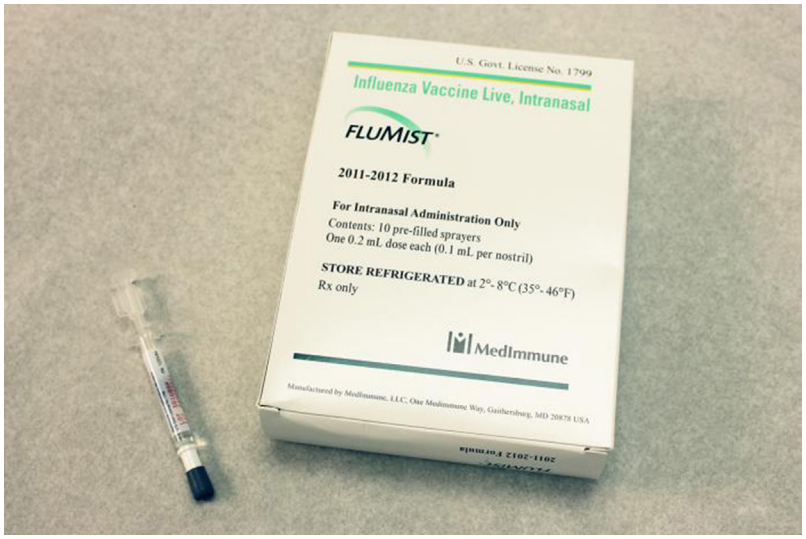

FIGURE 16-5 A box containing 10 prefilled FluMist® live attenuated intranasal vaccine (LAIV) sprayers, alongside of which was a single sprayer, which will be used to deliver the vaccine into the nasal cavity of the recipient. *Centers for Disease Control and Prevention (CDC) photograph by Douglas Jordan, M.A.*

FIGURE 16-6 Nurse administering a vaccination for a young boy. *Centers for Disease Control and Prevention (CDC) photograph by Judy Schmidt.*

using the current technologies and manufacturing approaches. Newer flu vaccine production methods include a cell-based approach approved in the United States by the Food and Drug Administration (FDA) in 2012. The first approved cell-culture flu vaccine was called Flucelvax. Instead of incubating eggs, vaccine viruses are cultured mammalian cells, purified and tested for use in vaccine. In most cases, to achieve necessary immunity with any inactivated virus, two doses are necessary to activate and sustain an immune response. The newest and fastest process uses recombinant technology. Approved in 2013 under the name, Flublok, the recombinant vaccine is one produced without using egg products or actual virus. Instead, Flublok uses an influenza virus protein made through genetic modification of a virus that infects insect cells. The virus produces an influenza protein that stimulates the immune response (FDA, 2015).

Vaccination rates following pandemic campaigns will vary. In multiple studies, several factors increased the likelihood of being vaccinated during the 2009 H1N1 pandemic: being a member of a priority group (healthcare worker, having children younger than 5 in the household, having a chronic condition with increased risk for complications from H1N1); having a history of seasonal flu vaccination and having a medical provider. Gilmour and Hofmann (2010) also found nearly three-quarters of those who had not been vaccinated reported they did not think it was necessary. Delays in vaccine distribution and delivery, relying on specialty care physicians for vaccinations (other than obstetricians) and a longer pandemic locally decreased vaccine rates (Davila-Payan et al., 2014). In the United States, vaccine rates were lower in some ethnic minorities because of fears of being used for experimentation. Public messaging must be culturally sensitive and multiple layers of communications strategies need to be applied in order to reach the most vulnerable populations.

Antiviral drugs are the most effective pharmaceutical options immediately available for managing an avian influenza pandemic (Schunemann et al., 2007). Although there are multiple drugs approved by the U.S. FDA for treatment and prevention of influenza, in recent years several strains of influenza show resistance to many previously prescribed antiviral drugs (CDC, 2006b). Using predictive modeling based on WHO criteria for a pandemic, Gani et al. (2005) suggests having antiviral access, through stockpiling or immediate commercial availability, with enough available to treat 25% of the population could reduce hospitalizations by 50–75%. In the 2009 influenza A (H1N1) pandemic, an assessment of the efficacy of antiviral use confirmed this, especially among the age group of 18–64 years (Atkins et al., 2011). Communities need to develop strategies for allocating antiviral medications when in short supply while awaiting development and distribution of strain-specific vaccine.

There is also an important role for antimicrobial drugs in pandemic influenza preparedness and response. Secondary bacterial infections are a common cause of death among those who die from influenza-related complications. In fact, about one-quarter of those who die from seasonal influenza are found with coinfections from bacterial infections as major factors in mortality (Bhat et al., 2005; Lim et al., 2001). It is important to determine the organism's susceptibility to the antimicrobial drug selected. It is also crucial to effectively triage those needing antimicrobial therapy so individuals with weak immune function receive priority treatment (Gupta et al., 2008).

Prevention and Preparedness

The WHO tracks seasonal influenza reports from around the world and analyzes data for anomalies that may signal the emergence of a novel influenza strain. Participating nations follow a set of international health regulations that include obligations to notify the WHO of any event that may constitute a public health emergency reaching the level of international concern. Nearly all nations have established processes for detecting and responding to emerging infectious disease threats. Influenza, however, receives more attention and resources than any other infectious disease threat given the potential for severe consequences associated with a novel pathogenic strain. Even the annual flu seasons have a tremendous global health impact. For example, over the past several decades the United States has experienced an increasing trend in the number of hospitalizations associated with seasonal influenza with the average number reaching over 200,000 per year (Thompson et al., 2004).

There are several measures that can be instituted to reduce the risk of influenza infection. These measures include both pharmaceutical and nonpharmaceutical interventions. The primary pharmaceutical measure for influenza is vaccination. As stated earlier, with an emerging pandemic influenza strain, a rapid, dramatic shift has occurred in the virus that will not allow sufficient time to incorporate the new strain into a vaccine before the pandemic is already spreading. There will likely be a delay of several months using the current vaccine production processes.

Public Messaging: Individual Influenza Prevention Tips

1. Get a flu shot every year. Even if the current vaccine does not protect specifically against avian influenza, it offers some protection against influenza and may reduce the overall disease severity during a pandemic.
2. Wash hands often with soap and water or use alcohol-based hand cleaner. Hand washing decreases risk for all sorts of illnesses including influenza.
3. Avoid touching your face. Touching your eyes, nose, and mouth may transfer virus from your hands and infect you with the virus.
4. Clean frequently touched surfaces often, including door handles, hand rails, cell phones, etc.
5. Cover your mouth when you cough or sneeze. Cough into your elbow and not your hand.
6. Stay away from those who are ill.
7. Avoid crowded congregate settings when there is illness in the community.
8. Stay home when ill and for at least 24 hours until after the fever is gone.
9. Avoid unnecessary travel when illness is prevalent. Take extra precautions when traveling.
10. Use antiviral medications, if your healthcare practitioner prescribes them, to decrease illness severity and to shorten the time you are sick. Antiviral medications can also prevent serious flu complications in those at high risk.

The CDC simplified these measures into a program called, *"Take 3" Actions to Fight the Flu*. It simplifies the 10 messages listed here into (Fig. 16-7):

1. Take time to get a flu vaccine.
2. Take everyday preventive actions to stop the spread of germs.
3. Take antiviral medications if your healthcare provider prescribes them.

FIGURE 16-7 "Take 3" Actions to Fight the Flu. A CDC influenza prevention education initiative. Available at: http://www.cdc.gov/flu/protect/preventing.htm. *Image courtesy of* www.Flu.gov, *a U.S. government website managed by the U.S. Department of Health and Human Services.*

In allocating scarce resources, antiviral medications may be used early in a pandemic for close contacts of initial cases and to contain disease clusters. Close contacts may include family members, friends, coworkers, healthcare providers, and fellow travelers on aircraft, buses, etc. The targeted use of antiviral medications can contain an outbreak or reduce individual and public health impact. The use of antiviral medications can also prevent cases in high-risk facilities such as long-term care or in well-defined regions such as military installations or school campuses. Strategies for use of antiviral medications for prevention and treatment may change during a pandemic. Early in the pandemic to a new region, it may be best to use antiviral medications to prevent infections. However, once influenza cases begin to spread across a community, priority antiviral allocation should be given to those with severe illness to improve their outcomes.

Nonpharmaceutical intervention measures offer the best or sometimes the only option for some regions. With billions of people at risk during a pandemic, there will not be adequate pharmaceutical measures to go around in the foreseeable future (WHO, 2005). There are several nonpharmaceutical interventions that offer the best prevention: hand washing, isolation, quarantine, and social distancing. The primary nonpharmaceutical intervention is hand washing. It is the most effective, most underrated measure to prevent illness. Isolation of those who are sick from those who are healthy is another fundamental nonpharmaceutical measure. Isolating sick patients in hospitals or at home should be undertaken with appropriate personal protective equipment if available. During a pandemic, hospitals may be full, and many who are able to care for themselves, or who have an adequate support system to provide care, should isolate themselves from others to reduce the risk of additional virus transmission. There are also those who are not yet ill but may have been exposed to the virus. These individuals may choose self-quarantine. Others with no illness or known exposure may choose social distancing by not attending social functions, limiting time in crowds, and/or wearing protective face masks. The concept is the same for all these prevention measures. In the context of prevention, the primary distinction between isolation, quarantine, and social distancing is the health status of the person taking action to stay away from others.

With the growing global threat of avian influenza, in fall 2005, the White House released the U.S. National Strategy for Pandemic Influenza. The U.S. approach remains essentially the same today with three steps:

1. Stopping, slowing, or otherwise limiting the spread of a pandemic to the United States
2. Limiting the domestic spread of a pandemic, and mitigating disease, suffering, and death
3. Sustaining infrastructure and mitigating impact to the economy and the functioning of society.

These steps are generalizable to all nations and include delaying or stopping a pandemic before it reaches a point of entry, reducing the spread of illness and mitigating suffering and death, and sustaining society, critical infrastructure, and the economy. The strategy also defines three pillars on which these activities are sustained. They include preparedness and communications, surveillance and detection, and response and containment (HSC, 2005). With this strategic vision, pandemic preparedness funding and associated requirements began arriving in 2006 for state and local governments to initiate local plans and begin training and exercising for a pandemic. Although this vision seems relatively simple, the challenge rests in translating it into tangible preparedness activities that federal, state, and local governments can take to enhance future response. This must be accomplished in a setting that includes profound challenges for sustainment of critical infrastructure, limitations on the mobility of people and goods, and a strain on the global economy.

Pandemic Lessons Learned from the Past 100 Years

1. No two pandemics are alike. There are differences in mortality, severity, and patterns of spread.
2. The need for rapid hospital surge capacity is a common factor in all pandemics.
3. Pandemic viral strains are more lethal and often cause severe disease in unlikely age groups, such as young, healthy adults.
4. Pandemics occur in waves. Age groups and geographical areas not affected initially are more likely to be vulnerable in subsequent waves. Subsequent waves are often more severe.
5. Virological surveillance is often the key to alerting public health agencies to a coming pandemic by isolating and characterizing the virus, and making it available to vaccine manufacturers.
6. Over the centuries, most pandemics have originated in parts of Asia where dense populations of humans live in close proximity to ducks and pigs.
7. Historically, public health interventions delay international spread of pandemics, but do not stop them. Quarantine and travel restrictions have little effect on viral disease spread.
8. Delaying disease spread can flatten the epidemiological peak, thus distributing cases over a longer period of time. Having fewer people ill at a given time increases the likelihood medical and other essential services can be maintained and reduces patient surge capacity needs (Fig. 16-8).
9. The impact of vaccines on a pandemic remains to be demonstrated. In 1957, 1968, vaccine manufacturers responded with too little vaccine, too late into the disease spread to have an impact.

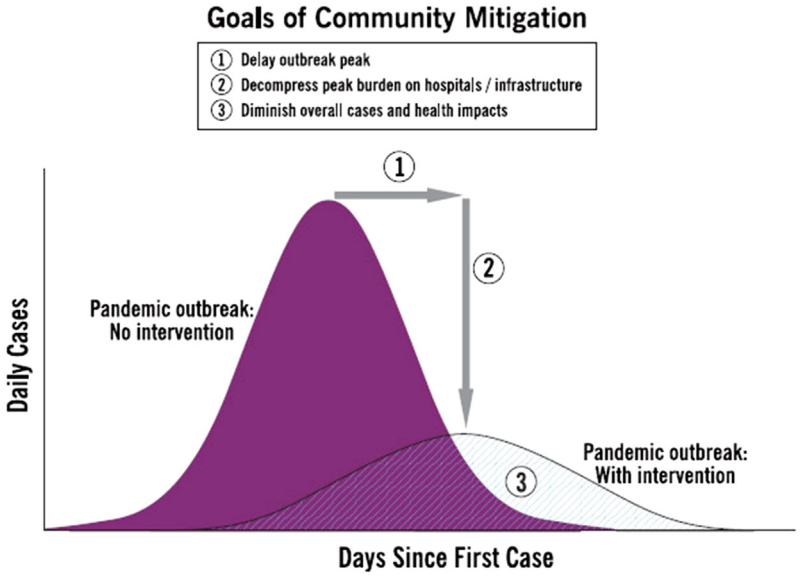

FIGURE 16-8 The goal of community mitigation measures during a pandemic is to compress the peak number of cases and keep the number of ill at any given time as manageable as possible. *U.S. Department of Health and Human Services, Community Strategy for Pandemic Influenza Mitigation (U.S. Department of Health and Human Services, 2007).*

10. Countries with domestic manufacturing capacity will be the first to receive vaccines.
11. The tendency of pandemics to be more severe in later waves may extend the time before large supplies of vaccine are needed to prevent severe disease in high-risk populations.
12. Regions with good annual influenza vaccination programs have experience in the logistics of vaccine administration to at least some groups requiring priority protection during a pandemic.

Adapted from Avian influenza: Assessing the pandemic threat. World Health Organization, pp. 31–33. Available at: http://www.who.int/influenza/resources/documents/h5n1_assessing_pandemic_threat/en/.

Immediate Actions

One of the most critical actions that a public health system can take in preventing and responding to a pandemic is health surveillance and monitoring the incidence of influenza. Reporting influenza-like–illness (ILI) through direct reporting by healthcare providers or through healthcare system reporting can indicate surges in possible cases as well as identify circulating strains. This information can be used to rapidly deploy pharmaceutical interventions and implement social distancing actions. Healthcare providers can report ILI through the U.S. Influenza Sentinel Provider Surveillance Network where the

total number of ILI is reported and a number of patient samples are tested for influenza virus for genetic typing. Syndromic surveillance systems such as Biosense and ESSENCE can indicate emergency department utilization for ILI and assist monitoring for impact. Viral surveillance can also indicate the incidence of antiviral resistance. The WHO collects influenza surveillance data and provides global information through its Global Influenza Surveillance and Response System (Fig. 16-9).

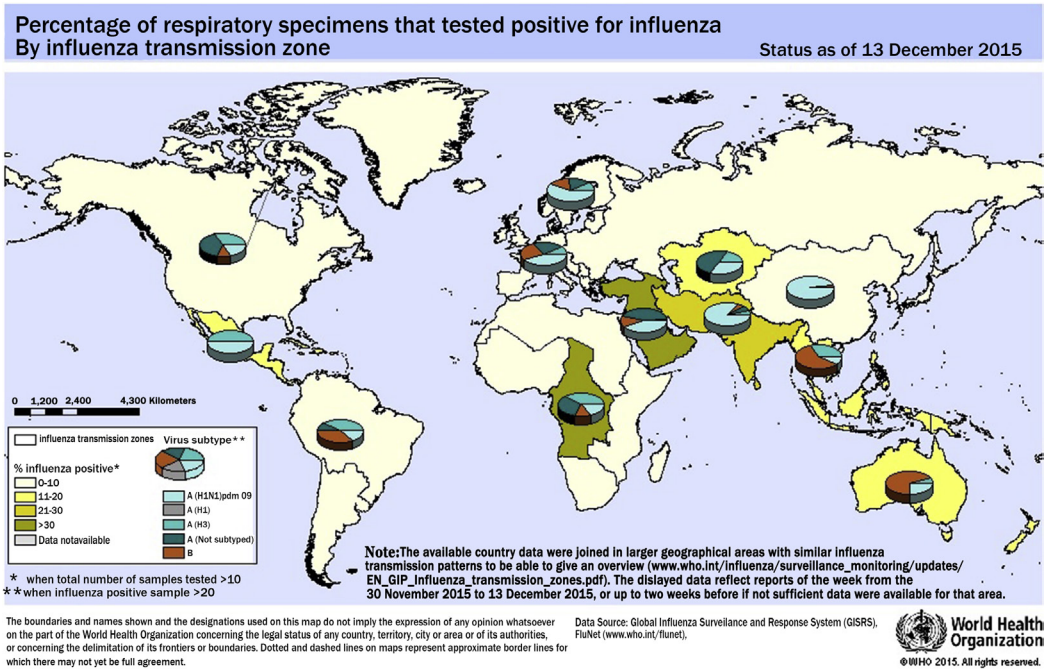

FIGURE 16-9 Sample WHO Influenza Summary Report. *Available at:* http://www.who.int/influenza/surveillance_monitoring/en/.

In 2013, the WHO updated their pandemic alert system from six phases (WHO, 2009) to four. These pandemic phases provide a global snapshot of a pandemic based upon the monitoring of virological, epidemiological, and clinical data. The phase determination is one of three pandemic preparedness and response tools used by the WHO to communicate and coordinate a pandemic response. The WHO director-general can also declare a Public Health Emergency of International Concern (PHEIC) or issue a Pandemic Declaration. Each of these declarations is accompanied by temporary recommendations or regulatory actions for member states (WHO, 2013).

1. Interpandemic: The period between pandemics where WHO and member states support preparedness activities and capacity development.

2. Alert: Issued when a new influenza subtype with pandemic potential is identified. Global influenza risk assessments are carried out according to international health regulations. Member states are asked to increase overall vigilance and initiate advisory groups and partner networks. Antiviral measures may be staged and prepared for use to control the introduction and spread of a novel virus.
3. Pandemic: Issued when a novel influenza strain spreads globally. Risk assessments are accomplished using virologic, epidemiologic, and clinical data. A pandemic is declared and responses are initiated by member states and supported by WHO based upon a global risk assessment.
4. Transition: Global risk drops, prompting stepdowns in global actions and response activities. Based upon ongoing global risk assessments, responses are scaled and consideration is given to modify or terminate the PHEIC.

The illustration below depicts how the WHO pandemic phases can transpire. It is a global picture so some nations can have no activity while others can have widespread cases before the WHO phase is elevated or dropped. The phases do not have a clean shift from one phase to the next. For example, the transition from the alert phase to the pandemic phase may not align perfectly with the global epidemiological curve. The scale is the "global average" of pandemic influenza cases (Fig. 16-10).

The CDC also updated the U.S. framework for pandemic influenza preparedness and response following the H1N1 pandemic. Updated guidance was released in 2014

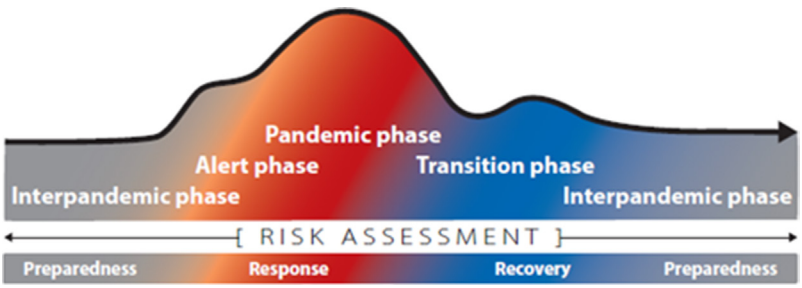

FIGURE 16-10 WHO pandemic phases (WHO, 2013).

(Holloway et al., 2014). The framework displays the progression of a pandemic with defined intervals triggering specific actions. This facilitates better federal, state, and local planning and enhances response coordination. The CDC framework has six defined intervals (Fig. 16-11):

1. Investigation Interval: A novel influenza virus with the potential to be a human health threat is identified and investigated anywhere in the world.

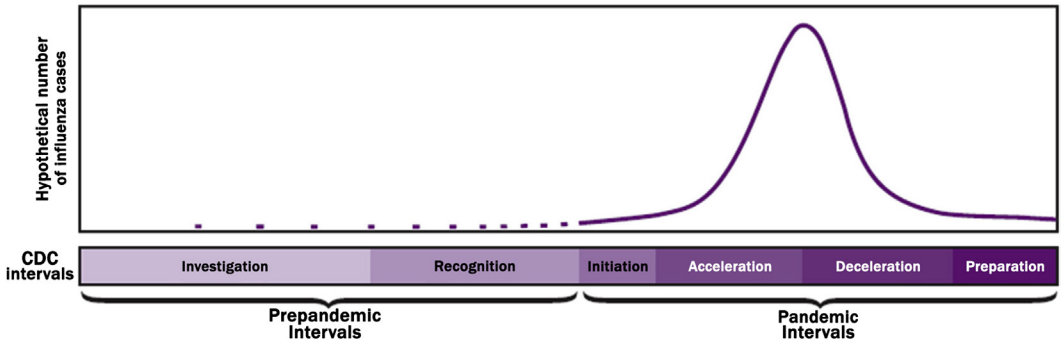

FIGURE 16-11 U.S. Preparedness and response framework for novel influenza A virus pandemics: CDC intervals (Holloway et al., 2014).

2. Recognition Interval: A novel influenza virus displays potential for ongoing human-to-human transmission. This may include increasing numbers or clusters of human cases.
3. Initiation Interval: The virus displays efficient and sustained human-to-human transmission. This is most apparent in institutional or family outbreak attack rates (>20%) and in the number of transmission generations (3 or more linked cases).
4. Acceleration Interval: Consistently increasing influenza cases demonstrating established disease transmission.
5. Deceleration Interval: Consistently decreasing influenza cases demonstrating the pandemic has passed its peak and is no longer accelerating.
6. Preparation Interval: Low numbers of influenza cases resulting in scaling back response activities, focusing on recovery and preparation for subsequent waves.

Like the WHO pandemic phases, these intervals provide a common reference for communicating the current pandemic risk level. With each increase in pandemic intervals, a variety of response measures are instituted. The intervals address the need for triggers. As events unfold leading up to a pandemic, it is essential to maintain a common frame of reference to understand when actions must be taken. There is no way to predict the timeframe for changes between the intervals. It may take days or years to move up or down from one interval to another. This variable timeline underscores the importance of coordinated pandemic preparedness planning. The six intervals do not run concurrently with the WHO phases (see Table 16-2). The intervals for U.S. government actions are based on the specific threat to the U.S. population.

Table 16-2 Preparedness and Response Framework for Novel Influenza A Virus Pandemics: A Crosswalk of the World Health Organization Phases and CDC Intervals, with Federal and State/Local Indicators (Holloway et al., 2014)

World Health Organization Phases	CDC Intervals	Federal Indicators for CDC Intervals	State/Local Indicators for CDC Intervals
Interpandemic phase: Period between influenza pandemics	**Investigation:** Investigation of novel influenza A infection in humans or animals	Identification of novel influenza A infection in humans or animals anywhere in the world with potential implications for human health	Identification of novel influenza A infection in humans or animals in the United States with potential implications for human health
Alert phase: Influenza caused by a new subtype has been identified in human	**Recognition:** Recognition of increased potential for ongoing transmission of a novel influenza A virus	Increasing number of human cases or clusters of novel influenza A infection anywhere in the world with virus characteristics, indicating increased potential for ongoing human-to-human transmission	Increasing number of human cases or clusters of novel influenza A infection in the United States with virus characteristics indicating increased potential for ongoing human-to-human transmission
Pandemic phase: Global spread of human influenza caused by a new subtype	**Initiation:** Initiation of a pandemic wave	Confirmation of human cases of a pandemic influenza virus anywhere in the world with demonstrated efficient and sustained human-to-human transmission	Confirmation of human cases of a pandemic influenza virus in the United States with demonstrated efficient and sustained human-to-human transmission
	Acceleration: Acceleration of a pandemic wave	Consistently increasing rate of pandemic influenza cases identified in the United States, indicating established transmission	Consistently increasing rate of pandemic influenza cases identified in the state, indicating established transmission
	Deceleration: Deceleration of a pandemic wave	Consistently decreasing rate of pandemic influenza cases in the United States	Consistently decreasing rate of pandemic influenza cases in the state
Transition phase: Reduction in global risk, reduction in response activities, or progression toward recovery actions	**Preparation:** Preparation for future pandemic waves	Low pandemic influenza activity but continued outbreaks possible in some jurisdictions	Low pandemic influenza activity but continued outbreaks possible in the state

Each interval triggers specific local activity. Many of the activities extend and build upon the efforts of previous intervals. These examples assume an existing pandemic preparedness program (CDC, 2014a). The listed activities are not intended to be exhaustive but rather to serve as general examples of local preparedness and

response activities when transitioning to subsequent intervals over the course of a pandemic:

Investigation Interval

- Review and exercise response plans.
- Maintain and enhance influenza and respiratory virus surveillance systems.
- Investigate novel influenza infections in humans and animals.
- Report cases according to the Nationally Notifiable Diseases Surveillance System.
- Advise healthcare providers to promptly diagnose and treat influenza.

Recognition Interval

- Consider activation triggers for emergency operations centers.
- Enhanced influenza surveillance.
- Investigate and report cases.
- Confirm suspected cases at a public health laboratory.
- Prepare for nonpharmaceutical interventions.

Initiation Interval

- Consider activation of emergency operations centers and public health emergency declarations.
- Implement nonpharmaceutical interventions.
- Monitor surge demands in healthcare facilities.
- Implement mass vaccination campaigns.
- Disseminate risk communication messages.

Acceleration Interval

- Monitor the effectiveness of response.
- Transition surveillance from individual case confirmation to syndromic surveillance.
- Provide laboratory confirmation only as required for virologic surveillance.
- Activate and expand community mitigation measures.
- Continue mass vaccination campaigns.

Deceleration Interval

- Review response activities and scale them proportionate to the situation.
- Continue severe disease and syndromic surveillance.
- Assess need for community mitigation measures and plan for cessation.
- Initiate reduction or cessation of surge capacity strategies.
- Continue vaccinations as appropriate.

Preparation Interval

- Consider deactivation of emergency operations centers.
- Prepare for subsequent waves.

- Return to routine laboratory interpandemic virologic surveillance.
- Replenish stockpiles or caches.
- Continue to vaccinate.

Many preparedness and response activities undertaken by the U.S. during a future pandemic may be triggered by a CDC evaluation tool called the Influenza Risk Assessment Tool or IRAT. The IRAT uses 10 scientific measures of the risk for emergence of a novel influenza virus and its public health impact. Each of the 10 criteria is used in a scoring system to depict pandemic risk. This includes "low risk" with scores between 1 and 3, "moderate risk" with scores between 4 and 7, and "high risk" for scores between 8 and 10. These outcomes are reviewed and weighted according to the risks of emergence and public health impact (CDC, 2014b). These 10 criteria are grouped into three categories:

Properties of the Virus

1. Genomic variation: Genetic characteristics important for human infections and disease.
2. Receptor binding: Whether the preferred viral host is animal or human and the types of cells it infects (eg, cells and tissue in the nose verses those deep in the lungs).
3. Transmission in lab animals: Displayed through airborne or contact transmission in a lab setting.
4. Antiviral susceptibility/resistance: Effectiveness of treatment with antiviral drugs (eg, oseltamivir, zanamivir and M2 blockers).

Attributes of the Population

1. Existing population immunity: Susceptibility to infection and severity of illness based upon age, geographic area, or genetic factors.
2. Disease severity and pathogenesis: The severity of illness caused by a particular influenza virus in people and/or animals.
3. Antigenic relationship to vaccine candidates: How similar a novel influenza virus is compared to current or previously manufactured vaccine strains.

Ecology and Epidemiology

1. Global distribution in animals: How widespread an influenza virus is in animals (eg, limited area or from many different areas).
2. Infection in animal species: Animals impacted by the virus and the likelihood of human contact with them (eg, in wild birds or domestic birds).
3. Human infections: Whether human infections are occurring and under what circumstances (eg, human-to-human transmission or clusters of disease occurred verses transmission after direct and prolonged contact between humans and infected animals).

Once a pandemic begins to sweep across a community, it will likely overwhelm local acute care facilities and cause a ripple effect of patient surge that will strain services across a region, a state, and eventually the nation. To save as many lives as possible, the healthcare system

must remain functional and delivering the best care possible under whatever conditions arise (Toner et al., 2006). The strategy to accomplish this is to institute community measures to delay and compress the outbreak peak (see Fig. 16-8). As interventions are instituted, some cases of illness will be delayed and others prevented. As a result, the cases in a given region can be spread over a longer period of time. Even though some who delay their illness eventually become ill, as the cases are spread over a more manageable timeframe, the peak number of cases will be more manageable for providers making it easier to sustain essential services.

> *If a severe pandemic materializes, all of society could pay a heavy price for decades of failing to create a rational system of healthcare that works for all of us.*
>
> *Irwin Redlener, Director of the National Center for Disaster Preparedness at Columbia University's Mailman School of Public Health (Kristof, 2009).*

Although there are a variety of community measures that can be taken during a pandemic to reduce the risk of exposure and subsequent cases of illness, a balance is needed when instituting interventions. No intervention is without some economic or social cost. If individuals are isolated or quarantined, and there is no support system in place to provide essentials such as groceries and prescriptions, or services such as child care for ill parents of small children, there can be social disruption in addition to extended health effects. Economic protection measures may need to be considered to allow those who are ill to work from home or at least to have some assurance taking sick days will not result in job loss. A variety of consequences must also be considered when closing schools and day care centers or when discouraging public gatherings. Children are at increased risk of influenza transmission in both preschool contacts and school-age contacts. Viboud et al. (2004) found there was also an increased risk in contacts exposed to preschool index patients and school-age index patients compared with those exposed to adult index cases. However, there are substantial economic and social outcomes to school-related measures. If children are not in school or day care, some parents will be unable to work. Parents are also likely to congregate children who have been kept out of school in order to have child care and to provide a diversion for the children, thereby negating the desired social distancing. If mass transit and congregate gatherings are discouraged, a variety of industries will suffer. Social distancing interventions may be important to public health but must be used judiciously. If the impact is seen as too severe, the political and social consequences may be too burdensome and the public may not comply. On the other hand, if interventions are established too late, they may be ineffective.

Nonpharmaceutical Intervention Examples

1. Isolation of the sick at home or in healthcare settings. Limiting visitors especially those from high-risk groups (young, elderly, and those with chronic illnesses).
2. Voluntary quarantine of households with confirmed or probable influenza.
3. Closure of daycares, K–12 schools, colleges, and congregate institutions. This should be followed by reducing child contacts through social distancing.
4. Social distancing of adults including cancellation of large gatherings and altered work schedules.

The challenges of managing a pandemic are immense, and the limitations of government response at all levels are known. The nongovernment resources from businesses, faith-based organizations, and others will certainly play a major role in a community pandemic response. Even communities with relatively broad preparedness participation from these organizations have rarely identified and characterized the resources and support these organizations can offer during an actual pandemic. It is also not known what policies may be instituted by these organizations to support or counter nonpharmaceutical interventions, such as implementation of sick leave benefits. It is difficult to effectively strategize with the substantial gaps existing in current planning assumptions. Involving these organizations in preparedness activities will be an important step in an effective pandemic response.

Recovery Challenges

It seems pandemic preparedness and response is so ominous and complex that when a WHO pandemic phase is reached, the planning stops. It is important to consider the post influenza pandemic scenarios and extend the process well beyond where many plans currently stop. For example, if there are significant fatalities within a certain demographic, special challenges for handling of human remains will emerge. If there are substantial numbers of adult losses, the secondary impact may be the loss of primary caregivers for children in some urban communities. If the losses are more among the working population, there are essential businesses and services that may be short-handed and unable to perform indispensable functions. This inoperability will result in a long-term economic ripple as production decreases, investment capital is diminished and further production is reduced. The healthcare sector is particularly vulnerable because healthcare workers will be repeatedly exposed. The system may suffer excessive losses, compromising the availability of staff or the standard of care. Even when the pandemic has resolved, critical infrastructure may take some time to fully recover. There are many unknowns in predicting what special challenges may result from a pandemic, making it critically important to push forward in the planning, training, and exercising of processes to include the recovery component addressing these possibilities. This should include consideration for a variety of scenarios as well as the mental/behavioral health impact and other resultant long-term issues.

Summary

Pandemic influenza has occurred at fairly regular intervals throughout history and will be repeated (Fig. 16-12). There are significant differences between each of these historical outbreaks and there will certainly be unique, unanticipated aspects to any future pandemic. Many gaps remain in preparedness activities and contemporary social changes may work against an optimal pandemic response. Influenza virus diversity and mutation proclivity inhibit efforts toward universal vaccine development or wholly effective antiviral medication. For over a decade, H5N1 influenza in the avian populations across multiple continents has been considered a possible precursor to a pandemic. While it is not

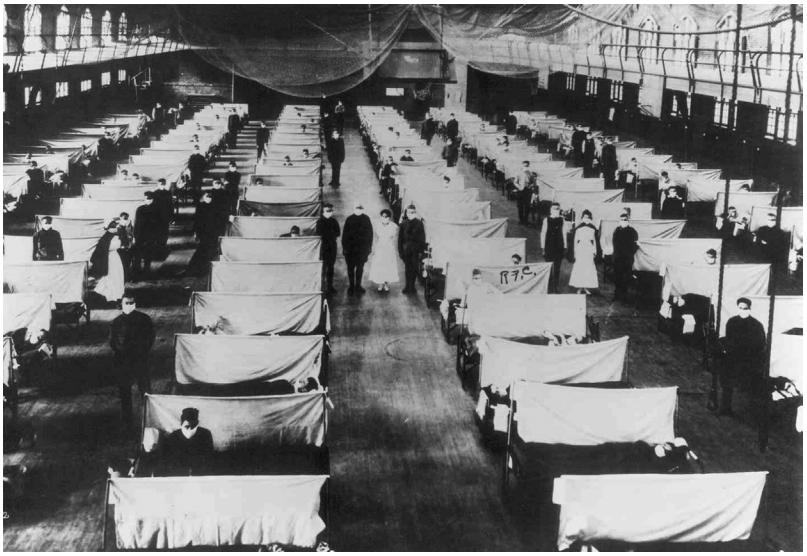

FIGURE 16-12 Mass care during the 1918 flu pandemic. *Department of Health and Human Services. Available at:* http://www.flu.gov/pandemic/history/1918/.

possible to predict that H5N1 will be next, it is certain another influenza virus will emerge, just as H1N1 did in 2009–10.

There are a number of positive factors regarding pandemic preparedness. Tremendous strides have been made in pharmaceuticals, critical care, and public health interventions. The WHO and public health organizations around the world are collaborating closely on monitoring the progress of H5N1 in both human and animal populations. Unprecedented international coordination will occur if and when the pandemic phase is elevated. In the United States, the recent investment in public health preparedness following the terrorist attacks of 2001 and more recent investments specifically in pandemic preparedness for H5N1 in 2006 and again for H1N1 in 2009 have filled several gaps in a public health infrastructure that had been eroding for decades.

Websites

Centers for Disease Control and Prevention, Influenza. http://www.cdc.gov/flu/.

Centers for Disease Control and Prevention, Influenza Risk Assessment Tool (IRAT). http://www.cdc.gov/flu/pandemic-resources/tools/risk-assessment.htm.

Centers for Disease Control and Prevention, CDC Intervals for a Novel Influenza A Virus Pandemic: State/Local and Federal Indicators, Decisions, and Actions. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr6306a2.htm.

Centers for Disease Control and Prevention, Updated Preparedness and Response Framework for Influenza Pandemics. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr6306a1.htm.

Centers for Disease Control and Prevention, Recommendations of the Advisory Committee on Immunization Practices (ACIP). http://www.cdc.gov/vaccines/hcp/acip-recs/.

Centers for Disease Control and Prevention, Resources for Pandemic Flu. www.cdc.gov/flu/Pandemic/.

Center for Infectious Disease Research and Policy, Pandemic Influenza. http://www.cidrap.umn.edu/infectious-disease-topics/pandemic-influenza.

European Centre for Disease Prevention and Control (ECDC), Influenza. http://ecdc.europa.eu/en/healthtopics/influenza/Pages/home.aspx.

European Influenza Surveillance Network (EISN). http://ecdc.europa.eu/en/healthtopics/influenza/EISN/Pages/index.aspx.

Food and Agriculture Organization of the United Nations, Avian Influenza. www.fao.org/avianflu/en/index.html.

United Kingdom, Department for Environment, Food, and Rural Affairs, Avian Influenza. https://www.gov.uk/avian-influenza-bird-flu.

U.S. Department of Agriculture, Avian Influenza (Bird Flu). http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=avian_influenza.html.

U.S. Department of Health and Human Services, The Great Pandemic: The United States in 1918–1919. http://www.flu.gov/pandemic/history/1918/.

U.S. Department of Health and Human Services, One-stop Access to U.S. Government Avian and Pandemic Flu Information. www.pandemicflu.gov/.

U.S. Department of Homeland Security, National Strategy for Pandemic Flu. http://www.dhs.gov/national-strategy-pandemic-flu.

U.S. Food and Drug Administration, Influenza Virus Vaccine Safety & Availability. http://www.fda.gov/BiologicsBloodVaccines/SafetyAvailability/VaccineSafety/UCM110288.

U.S. Geological Survey, Avian Influenza. http://www.nwhc.usgs.gov/disease_information/avian_influenza/index.jsp.

Wildlife Conservation Society, Avian Influenza (H5N1). http://www.wcs.org/conservation-challenges/wildlife-health/disease-investigations/avian-influenza-h5n1.aspx.

World Health Organization, Influenza at the Human-Animal Interface (HAI). http://www.who.int/influenza/human_animal_interface/en/.

World Health Organization, Epidemic and Pandemic Alert and Response, Current WHO Phase of Pandemic Alert. www.who.int/csr/disease/avian_influenza/phase/en/index.html.

World Health Organization, Epidemic and Pandemic Alert and Response, Global Influenza Surveillance. www.who.int/csr/disease/influenza/influenzanetwork/en/.

World Health Organization, Avian Influenza. http://www.who.int/mediacentre/factsheets/avian_influenza/en/.

World Health Organization, Influenza (Seasonal). http://www.who.int/mediacentre/factsheets/fs211/en/.

World Health Organization, Pandemic Influenza Risk Management, WHO Interim Guidance. http://www.who.int/influenza/preparedness/pandemic/influenza_risk_management/en/.

References

Atkins, C.A., Patel, A., Taylor, T.H., Biggerstaff, M., Merlin, T.L., Dulin, S.M., Erickson, B.A., Borse, R.H., Hukler, R., Meltzer, M.I., 2011. Estimating the effects of anti-viral drug use during pandemic (H1N1) 2009 outbreak. EID 17 (9), 1591–1598.

Badae, N., Bashir Aamir, U., Mehmood, M.R., Nisar, N., Alam, M.M., Kazi, B.M., Zaidi, S.S.Z., November 2013. Influenza virus surveillance in Pakistan 2008–2011. PLoS One 8 (11), e79959.

Bhat, N., Wright, J.G., Broder, K.R., et al., 2005. Influenza-associated deaths among children in the United States, 2003–2004. N. Engl. J. Med. 353, 2559–2567.

Burnet, F., Clark, E., 1942. Influenza: A Survey of the Last 50 Years in the Light of Modern Work on the Virus of Epidemic Influenza. MacMillan, Melbourne, Australia.

Centers for Disease Control and Prevention (CDC), 2006a. Pandemic influenza storybook: personal recollections from survivors, families, and friends. Angela J. Deokar CDC, Department of Health and Human Services. www.pandemicflu.gov/storybook/stories/courage/otto/index.html.

Centers for Disease Control and Prevention (CDC), 2006b. Health Alert: CDC Recommends Against the Use of Amantadine and Rimantadine for the Treatment or Prophylaxis of Influenza in the United States during the 2005–06 Influenza Season. Available at: http://stacks.cdc.gov/view/cdc/25151.

Centers for Disease Control and Prevention (CDC), September 26, 2014a. Appendix: CDC intervals for a novel influenza a virus pandemic: state/local and federal indicators, decisions, and actions. recommendations and reports. Morb. Mortal. Wkly. Rep. (MMWR) 63 (RR06), 10–18. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/rr6306a2.htm.

Centers for Disease Control and Prevention (CDC), 2014b. Influenza Risk Assessment Tool (IRAT). Available at: http://www.cdc.gov/flu/pandemic-resources/tools/risk-assessment.htm.

Cox, N.J., Subbarao, K., 2000. Global epidemiology of influenza: past and present. Ann. Rev. Med. 51, 407–421.

Davila-Payan, C., Swann, J., Wortley, P.M., 2014. System factors to explain H1N1 state vaccination rates for adults in US emergency response to pandemic. Vaccine 32 (25), 3088–3093.

Food and Drug Administration, Center for Drug Evaluation and Research, 2008. Influenza (Flu) Antiviral Drugs and Related Information. Available at: www.fda.gov/cder/drug/antivirals/influenza/default.htm.

Frost, W.H., 1920. Statistics of influenza morbidity. Public Health Rep. 35, 584–597.

Gani, R., Hughes, H., Fleming, D., Griffin, T., Medlock, J., Leach, S., September 2005. Potential impact of antiviral drug use during a pandemic. EID 11 (9), 1355–1362.

Gilmour, H., Hofmann, N., 2010. H1N1 vaccination. Health Rep. 21 (4), 63–69.

Gupta, R.K., George, R., Nguyen-Van-Tam, J.S., 2008. Bacterial pneumonia and pandemic influenza planning. Emerg. Infect. Dis. 14, 1187–1192. Available at: http://wwwnc.cdc.gov/eid/article/14/8/07-0751_article.

Haimar, A.E., Santos, J.R., 2015. A stochastic recovery model of influenza pandemic effects on interdependent workforce systems. Nat. Hazards 77 (2), 987–1011.

Holloway, R., Rasmussen, S.A., Zaza, S., Cox, N.J., Jernigan, D.B., September 26, 2014. Updated preparedness and response framework for influenza pandemics. Morb. Mortal. Wkly. Rep. (MMWR) Recomm. Rep. 63 (RR06), 1–9. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/rr6306a1.htm.

Inamasu, T., Sudo, K., Kato, S., Deguchi, H., Ichikawa, M., Shimizu, T., Saito, T., 2012. Pandemic influenza virus surveillance, Izu-Oshima Island, Japan. Emerg. Infect. Dis. 18 (11), 1882–1885.

International Committee on Taxonomy of Viruses, 2006. Index of viruses—Orthomyxoviridae. In: Büchen-Osmond, C. (Ed.), ICTVdB—The Universal Virus Database, Version 4. Columbia University, New York. www.ncbi.nlm.nih.gov/ICTVdb/Ictv/fs_index.htm.

Johnson, N.P., Mueller, J., 2002. Updating the accounts: global mortality of the 1918–1920 "Spanish"-influenza pandemic. Bull. Hist. Med. 76, 105–115.

Kobasa, D., Takada, A., Shinya, K., et al., 2004. Enhanced virulence of influenza A viruses with hemagglutinin of the 1918 pandemic virus. Nature 431, 703–707.

Kristof, N.D., May 2, 2009. A Nation of Typhoid Marys. New York Times. Available at: http://www.nytimes.com/2009/05/03/opinion/03kristof.html?_r=0.

Lim, W.S., Macfarlane, J.T., Boswell, T.C., et al., 2001. Study of community acquired pneumonia etiology (SCAPA) in adults admitted to hospital: implications for management guidelines. Thorax 56, 296–301.

Louie, J.K., Acosta, M., Samuel, M.C., Matyas, B.J., Schechter, R., April 5, 2011. A review of adult mortality due to pandemic (H1N1) influenza A in California. PLoS One 6 (4), e18221. http://dx.doi.org/10.1371/journal.pone.0018221.

Manning, A., March 20, 2006. U.S. Expects Bird Flu This Year. USA Today. www.usatoday.com/news/health/2006-03-20-bird-flu_x.htm.

Marks, G., Beatty, W.K., 1976. Epidemics. Scribners, New York.

Morse, S.S., Garwin, R.L., Olsiewski, P.J., 2006. Next flu pandemic: what to do until the vaccine arrives? Science 314, 929.

Osterholm, M.T., 2005. Preparing for the next pandemic. N. Engl. J. Med. 352 (18), 1839–1842. http://content.nejm.org/cgi/content/full/352/18/1839.

Reperant, L.A., Kuiken, T., Osterhaus, A.D., 2012. Adaptive pathways of zoonotic influenza viruses: from exposure to establishment in humans. Vaccine 30 (30), 4419–4434.

Rosenau, M.J., Last, J.M., 1980. Maxcy-rosenau Preventative Medicine and Public Health. Appleton-Century-Crofts, New York.

Sheih, W., Blau, D.M., Denison, A.M., et al., 2010. 2009 pandemic influenza A (H1N1): pathology and pathogenesis of 100 fatal cases in the U.S. Am. J. Pathol. 177 (1), 166–175.

Sheu, T.G., Deyde, V.M., Okomo-Adhiambo, M., Garten, R.J., Xu, X., Bright, R.A., Gubareva, L.V., 2008. Surveillance for neuraminidase inhibitor resistance among human influenza A and B Viruses circulating worldwide from 2004 to 2008. Antimicrob. Agents Chemother. 52 (9), 3284–3292. http://dx.doi.org/10.1128/AAC.00555-08.

Schünemann, H.J., Hill, S.R., Kakad, M., et al., 2007. WHO rapid advice guidelines for pharmacological management of sporadic human infection with avian influenza (H5N1) virus. Lancet Infect. Dis. 7, 21–31.

Talkington, M., 2009. New antibodies block a range of influenzas. Nature. Published online 22 February 2009. Available at: http://www.nature.com/news/2009/090222/full/news.2009.116.html.

Thompson, W.W., Shay, D., Weintraub, E., Brammer, L., Bridges, C.B., Cox, N.J., Fukuda, K., 2004. Influenza associated hospitalizations in the US. JAMA 292 (11), 1333–1340.

Toner, E., Waldhorn, R., Maldin, B., et al., 2006. Hospital preparedness for pandemic influenza. Biosecur. Bioterror. 4 (2), 207–217.

U.S. Department of Health and Human Services, 2007. Interim Pre-pandemic Planning Guidance: Community Strategy for Pandemic Influenza Mitigation in the United States. Available at: http://www.flu.gov/planning-preparedness/community/community_mitigation.pdf.

U.S. Homeland Security Council (HSC), 2005. National Strategy for Pandemic Influenza. The White House, Washington, DC. Available at: http://www.flu.gov/planning-preparedness/federal/pandemic-influenza-strategy-2005.pdf.

U.S. Food and Drug Administration (FDA), 2015. Consumer Updates: The Evolution, and Revolution, of Flu Vaccines. Available at: http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm336267.htm.

Viboud, C., Boëlle, P.Y., Cauchemez, S., Lavenu, A., Valleron, A.J., Flahault, A., Carrat, F., 2004. Risk factors of influenza transmission in households. Br. J. Gen. Pract. 54 (506), 684–689.

Webster, R.G., Govorkova, E.A., 2006. H5N1 influenza—continuing evolution and spread. N. Engl. J. Med. 21, 2174–2177.

World Health Organization (WHO), 2005. Avian Influenza: Assessing the Pandemic Threat. Available at: http://www.who.int/influenza/resources/documents/h5n1_assessing_pandemic_threat/en/.

World Health Organization (WHO), 2009. Pandemic Influenza Preparedness and Response: A WHO Guidance Document. Available at: http://whqlibdoc.who.int/publications/2009/9789241547680_eng.pdf.

World Health Organization (WHO), 2013. Pandemic Influenza Risk Management: WHO Interim Guidance. Available at: http://www.who.int/influenza/preparedness/pandemic/GIP_PandemicInfluenzaRiskManagementInterimGuidance_Jun2013.pdf?ua=1.

17

Thunderstorms and Tornadoes

OBJECTIVES

- Describe the primary health threats associated with thunderstorms.
- List five ways emergency alerts can be quickly shared with the public.
- Explain the situational risks most commonly associated with lightning injuries.
- Describe lightning injury morbidity and mortality trends.
- List the three worst places to be during a tornado and why.
- Define the Enhanced Fujita (EF) Scale and associated mortality trends.
- List the basic ways to reduce tornado-related morbidity and mortality.
- Explain the tornado safety offered by different types of structures.
- Describe the public health issues resulting from postdisaster debris management.
- Explain the most effective public health measures for a post storm environment.

Introduction: The 2011 Joplin, MO, Tornado

It was a festive occasion for about 450 Joplin High School seniors. Amid a sea of maroon caps and gowns, cheers erupted and hats flew into the air with the final graduation pronouncement. But as the graduates, along with friends and families, made their way out of the Missouri Southern State University gymnasium, tornado warning sirens were sounding. There was stillness in the air as the crowd calmly made their way across the parking lot.

Joplin, MO, is located on the edge of the southern plains of the central United States in a region referred to as "tornado alley." This area experiences frequent tornadoes, especially in late spring and early fall. Tornado sirens regularly sound during these times and area residents typically carry on their daily activities while keeping an eye on the sky.

Among the graduates was Will Norton, a tall, outgoing, creative young man with a broad smile and great sense of humor. He enjoyed making videos and posting them on YouTube. The posted videos provided insights into his promising talents on both sides of the camera. His plan after graduation was to attend the prestigious Chapman University, Dodge College of Film and Media Arts. His close knit family enjoyed spending time together and had big plans to celebrate Will's high school graduation. A catered meal with friends and family awaited them at home. Will's mother and sister left the graduation ceremony before Will and his father Mark to finalize the party preparations. As they drove home, the sky grew dark and the inclement weather quickly intensified.

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Unbeknown to all, one of the deadliest tornadoes in history was about to enter the city limits of Joplin. Will's mother and sister arrived home just as the massive tornado hit. Tree branches and debris flew by as they quickly took shelter in their home. As the storm passed, it completely destroyed the homes across the street but spared theirs. Meanwhile, Will was driving home with his father sitting in the passenger's seat. As the massive tornado came into view, Mark told Will to pull over. But it was too late. Suddenly, Will's window blew out followed by the others. Debris flew throughout the SUV as it was lifted from the ground. Mark reached over and clenched his son tightly. Despite his father's best efforts to protect him, Will's seat belt snapped and he was flung through the sunroof.

The empty vehicle was discovered by his aunt and uncle about one block from Will's home shortly after the storm passed. They gathered belongings from the vehicle and returned to the Norton's home, reporting the dreadful news that they found the vehicle but there was no sign of Will or Mark. It appeared unlikely anyone could have survived. The family began a frantic search for the missing father and son. Crews on the ground combed through debris while calls were made to hospitals across the state. Mark was located in a local hospital with serious injuries. Will remained missing. A considerable social media campaign was launched. National news outlets featured the story of Will. Days passed and the search grew. Five days after the storm, Will's body was found in a pond near the wreckage of his SUV. It was the third time sonar had been used to search the pond, but the debris made it difficult to find Will's remains. Will Norton was one of the 158 individuals who perished that day in the single most deadly tornado to strike the United States since modern record-keeping began in 1950 (Fig. 17-1) (Norton, 2011; Sheridan, 2011).

FIGURE 17-1 Navy Chief Petty Officer Mike Shea assists a crane operator to move a wrecked vehicle during tornado cleanup efforts in Joplin, MO, on June 4, 2011. *U.S. Navy photograph by Lt. J.G. Ryan Sullivan.*

Thunderstorm and Tornado Definitions

Damage indicators (DI) List of 28 types of commercial buildings, residential structures, free-standing poles and towers, and trees which are evaluated on an 8-point scale for degrees of damage (DoD) to determine the Enhanced Fujita (EF) Scale rating of a tornado.

Degrees of damage (DoD) Eight-point scale used to classify the level of damage across the list of 28 types of manmade structures and trees (damage indicators) to determine the EF Scale rating of a tornado.

Downburst Strong downdraft resulting in an outward burst of damaging winds on or near the ground. Downburst winds can produce damage similar to a tornado.

Downdraft Small-scale column of air that rapidly sinks toward the ground, usually accompanied by precipitation. A downburst is the result of a strong downdraft.

Enhanced Fujita scale Modified version of the original Fujita Scale to more accurately assign a tornado a "rating" based on estimated wind speeds and related DoD using eight levels of damage to 28 indicators, including a variety of structures.

Fujita scale (F Scale) Scale describing wind damage intensity. All tornadoes, and some severe windstorms, are assigned a number from the 0-to-5 scale according to estimated wind speed and damage caused.

Funnel cloud Condensation funnel extending from the base of a thunderstorm, associated with a rotating column of air that is not in contact with the ground (not yet a tornado).

Hook (hook echo) Radar reflectivity pattern characterized by a hook-shaped extension of a thunderstorm echo, usually in the right-rear part of the storm relative to direction of motion. A hook is often associated with favorable conditions for tornado development.

Lightning Naturally occurring, high-voltage electrical discharge with very short duration. It can be within a cloud, between clouds, or between clouds and the ground.

Microburst Small, concentrated downburst of air affecting an area less than 2.5 miles (4 km) across. Most microbursts have a short duration, about 5 minutes, but some can last longer.

Multicell storm Common thunderstorm that develops updrafts along the leading edge of rain-cooled air. Individual cells in the system last 30–60 minutes but the entire system can last for hours. Multicell storms can produce hail, damaging winds, flooding, and sometimes tornadoes.

Multiple vortex Tornado with two or more funnels or debris clouds present at the same time, often rotating around a common center or each other. Multiple-vortex tornadoes may be especially dangerous.

Severe thunderstorm Thunderstorm with winds of at least 50 knots (57.5 mph/92.5 km/hour) and hail production of 0.75 in. (1.9 cm) or tornadoes.

Severe thunderstorm warning Issued by the US. National Weather Service to warn the public and response agencies when a severe thunderstorm is expected or is occurring. The warning will include where the storm is occurring, its direction of movement, and the primary threats expected from the storm.

Severe thunderstorm watch Issued by the U.S. National Weather Service when conditions are favorable for the development of severe thunderstorms in a defined area.

Shear (wind shear) Variation in wind speed and/or direction over a short distance. Shear generally refers to vertical wind shear, that is, the change in wind with height.

Shelf cloud Low, horizontal, wedge-shaped cloud associated with a thunderstorm front.

Squall line Line or band of active thunderstorms.

Straight-line winds Storm winds not associated with rotation, used to differentiate from tornadic winds.

Supercell Severe thunderstorm with updrafts and downdrafts that are nearly balanced allowing the storm to sustain for hours. Supercells are sometimes up to 10 miles (16 km) in diameter, reach heights of over 50,000 ft (15,200 m), and often produce large hail and tornadoes.

Tornado Rapidly rotating column of air that emerges from a thunderstorm, making contact with the ground. It has a destructive circulation causing damage and injury when it reaches the ground. However, the visible portion may not extend all the way to the ground.

Tornado warning Issued by the U.S. National Weather Service to warn the public and response agencies when a tornado is imminently likely to occur or is occurring. The warning will include where the storm is occurring and its direction of movement.

Tornado watch Issued by the U.S. National Weather Service to warn the public and response agencies when conditions are favorable for the development of severe thunderstorms and possible tornadoes in the area.

Wall cloud Area of clouds extending under a severe thunderstorm. Rotation of wall clouds sometimes produces a tornado.

Waterspout Tornado that reaches the surface of the water rather than the ground.

Thunderstorms

A thunderstorm is formed when moisture and rising warm air encounter weather factors providing lift. The lift is usually provided by a warm or cold front but can also be provided by mountain or sea breezes. Thunderstorms may be a single cloud, a cluster, or a line. A thunderstorm is considered "severe" when it has either winds gusting to greater than 50 knots (57.5 mph/92.5 kph), hail greater than 1 in. (2.5 cm) in diameter, or tornadoes. Thunderstorms average about 15 miles (24 km) in diameter and last about 30 minutes (NOAA, 2015a) Thunderstorm hazards include lightning, hail, heavy rain, strong winds, and tornadoes. The rain can contribute to riverine or flash floods, which are the most lethal aspect of thunderstorms. Flooding is addressed in detail in Chapter 11, Floods. Hail can be larger than a softball (5 in./12.7 cm) and cause severe damage to property, crops, and livestock. Winds

FIGURE 17-2 A severe thunderstorm in South Dakota, July 20, 2002. *Photograph courtesy of the U.S. National Weather Service.*

produced are either straight line or rotational. Rotational winds in the form of tornadoes are the most notorious, although straight line winds can drop from a thunderstorm cloud at over 100 mph. These powerful downbursts can cause damage similar to a tornado and are particularly dangerous to aircraft. Around the world, over 16 million thunderstorms occur each year, with about 2000 storms in progress at any given moment. The United States has more severe weather events than any other nation. Annually an average of 100,000 thunderstorms, 10,000 severe thunderstorms, 5000 floods, 1000 tornadoes, and an average of two deadly hurricanes hit the United States resulting in an estimated 500 fatalities and $15 billion in damage. In fact, about 98% of all federally declared disasters in the United States are storm related (NOAA, 2015b) (Fig. 17-2).

Lightning

Lightning produced by thunderstorms poses a serious threat. Positive and negative charges build inside storm clouds as moisture separates into water and ice at high altitudes within the clouds. Positive charges build in ice particles while negative charges build in water droplets. When enough energy builds between the two, energy is discharged as a bolt of light. Lightning can occur within a storm cloud or from cloud to cloud, but poses substantial risk when it travels from cloud to ground. Lightning produced by a thunderstorm has an incredible reach. Even when lightning is not apparent, it can strike up to 10 miles (16 km) from the storm's rainfall (Holle et al., 1995). The channel of air which lightning passes through can reach a temperature of nearly 50,000°F (27,760°C) and dissipate in a split second (NOAA, 2012a,b). Thunder results from the instant heating and cooling of the air channel.

It is estimated about 30 million lightning strikes hit the ground every year in the United States alone (Krider and Uman, 1995). There were 374 struck-by-lightning deaths recorded from 1995 to 2000, an average annualized rate of 0.23 death per 1 million persons (Adekoya and Nolte, 2005). Although there are millions of lightning strikes around the world each day, relatively few cause injury. A review of lightning strikes from 1959 to 1990 indicates an annual U.S. average of just over 250 lightning injuries and about 90 deaths per year (Lopez and Holle, 1995). About one-third of those struck by lightning die from their injuries. Of those who survive, nearly 75% experience some form of permanent disability (Cooper, 1980). Sixty-three percent of those who die are lost within the first hour of their injuries (Duclos and Sanderson, 1990). The vast majority of these injuries (92%) occur between May and September, and nearly three-quarters (73%) occur in the afternoon and evening. About half (52%) of those injured by lightning are engaged in outdoor recreational activities, including boating, swimming, horseback riding, playing sports, golfing, walking, mountain climbing, fishing, and camping. One-quarter (25%) are engaged in outdoor work activities, including riding a lawnmower or loading a truck. Others result from simply standing under a tree, storm watching, or when running for shelter (Lopez and Holle, 1995; NOAA, 2015c). Nearly all lightning injuries and fatalities are preventable (Fig. 17-3).

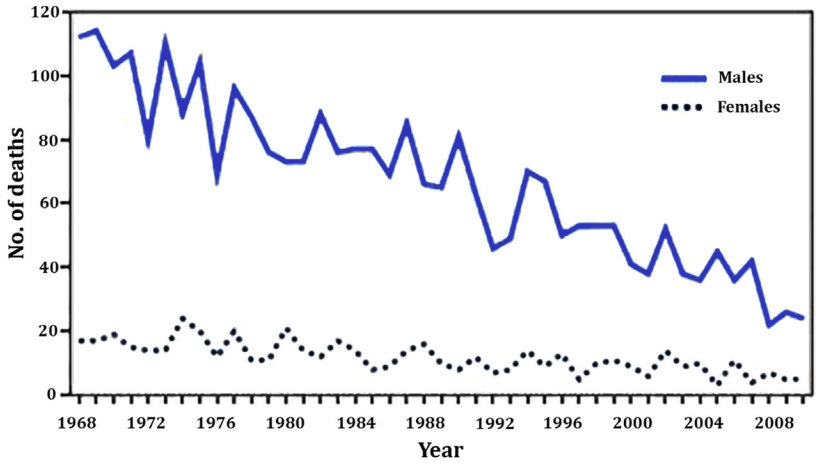

FIGURE 17-3 Number of deaths from lightning among males and females—National vital statistics system, United States, 1968–2010.

U.S. lightning deaths have consistently declined since the late 1960s. Since 1968, 85% of U.S. lightning deaths are male. Between 1968 and 2010, lightning deaths declined over 78% for males and 70% for females respectively (CDC, 2013).

Those between the ages of 15 and 34 years comprise just over 40% of the total fatalities. Interestingly, about one-third of lightning fatalities do not occur outside but result from lightning being conducted by metal wires, pipes, and surfaces into a building. This includes showers and faucets, electrical outlets, windows, and doors (CDC, 2014b). Outdoors, an individual may experience a direct lightning strike that is less common but most often fatal. There are also risks of "side flashes" where the electrical current jumps to a person from a nearby object that has been struck and streamer injuries where lightning current discharges from the ground upward. The most common cause of lightning deaths is ground current where the lightning strike electrical current travels across the ground from the point at which a strike has occurred. This is also a frequent cause of death among farm animals struck by lightning (NOAA, 2015c).

Tornadoes

Tornadoes are a destructive product of thunderstorms. Although tornadoes can occur almost anywhere, most occur within the United States. Tornadoes can have winds from 100 mph (160 kph) to over 300 mph (480 kph). Some can reach over 1 mile wide and remain on the ground for multiple miles. Once they are on the ground, tornadoes typically move forward at about 30 mph (48 kph). University of Chicago Professor T. Theodore

Table 17-1 Enhanced Fujita (EF) Scale

Scale	Wind Estimate 3-Second Gust	Typical Damage
EF0 (gale tornado)	65–85 mph 105–137 kph	Light damage: some damage to chimneys; tree branches broken off; shallow-rooted trees pushed over; sign boards damaged
EF1 (moderate tornado)	86–110 mph 138–177 kph	Moderate damage: roof damage; mobile homes pushed off foundations or overturned; moving cars blown off roads
EF2 (significant tornado)	111–135 mph 178–217 kph	Considerable damage: roofs torn off; mobile homes demolished; trains overturned; large trees uprooted; debris missiles generated; cars lifted
EF3 (severe tornado)	136–165 mph 218–266 kph	Severe damage: roofs and some walls torn off well-constructed houses; trains overturned; most trees uprooted; heavy cars lifted off the ground and thrown
EF4 (devastating tornado)	166–200 mph 267–322 kph	Devastating damage: well-constructed houses leveled; structures with weak foundations some distance; cars thrown and large debris missiles generated
EF5 (incredible tornado)	>200 mph >322 kph	Incredible damage: strong frame houses leveled; automobile-sized missiles fly in excess of 100 m (109 yd); trees debarked; incredible devastation

Adapted from National Oceanic and Atmospheric Administration, National Weather Service, The Enhanced Fujita Scale (EF Scale). Available at: http://www.spc.noaa.gov/efscale/.

Fujita developed the Fujita Tornado Damage Scale in 1971 to characterize the severity of tornadoes. It does not use actual wind measurements but estimates wind speeds based on observed damage. An updated or Enhanced Fujita (EF) Scale was introduced in 2007, which estimates wind speed using eight levels of damage to 28 indicators including a variety of buildings and free-standing structures (NOAA, 2007) (Table 17-1). However, the original F0–F5 categories are not significantly changed.

Tornadoes are possible in many regions of the world but most frequently occur in the central and southern United States (Fig. 17-4). The United States averages about 1200 tornadoes each year resulting in 60–65 deaths and 1500 injuries (NOAA, 2012a,b). Nearly 70% of all tornadoes are considered weak (EF0–EF1). They typically last less than 10 minutes and are responsible for less than 5% of tornado fatalities. About 30% of tornadoes are considered strong (EF2–EF3). These may be on the ground longer, up to 20 minutes or longer, and account for about 30% of all fatalities. The most violent tornadoes are relatively rare. EF4–EF5 tornadoes account for only 2% of all tornadoes. However, they account for about 70% of all fatalities (NOAA, 2009). These powerful storms have been known to remain on the ground for over 1 hour, causing massive damage and high morbidity and mortality (Figs. 17-5 and 17-6).

FIGURE 17-4 An EF4 tornado near Dimmitt, TX, June 2, 1995. *NOAA Photograph Library, photograph by Harald Richter.*

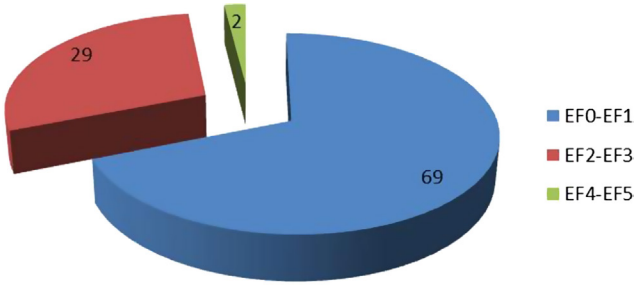

FIGURE 17-5 Frequency of tornado types on the enhanced Fujita scale.

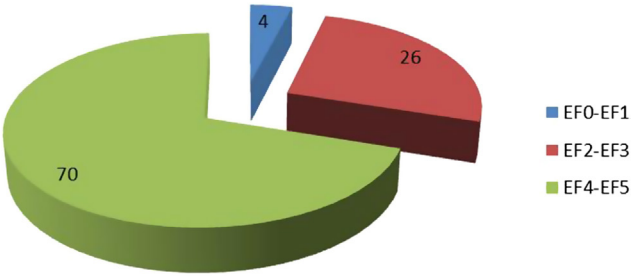

FIGURE 17-6 Fatalities resulting by tornado type on the EF scale.

Human Health Effects

The impact of severe storms on morbidity and mortality can be devastating. The major cause of storm-related death is flooding. However, secondary to high winds and tornadoes, crush injuries from collapsed structures and traumatic missile injuries from flying debris injure people every year as well. Many injuries are due to the vulnerability of manufactured or mobile homes. Storm shelters have proven to be an effective measure to reduce risk (CDC, 1992; Eidson et al., 1990; Liu et al., 1996). The elderly are also at higher risk (Glass et al., 1980). Reducing tornado-related morbidity and mortality relies on public education, warning systems, and access to storm shelters. It also requires individuals to be prepared to take protective action. During a devastating 1994 storm in Alabama, only 31% of those who heard the tornado warning actually took shelter (NOAA, 1996). Unfortunately, many individuals residing in areas of greatest tornado risk receive so many warnings with no recognized threat, they become apathetic and fail to take proper protective actions when a true, though perhaps unseen, threat is imminent.

Tornado-associated morbidity and mortality is influenced by a variety of factors. The characteristics of the tornado itself (eg, scale, intensity, duration, time of day, and geography), community population characteristics (demographics, population density, social vulnerability), individual attributes (experience, preparedness), and physical location of those in the path of a storm (outdoors, indoors, type of structure) (Hammer and Schmidlin, 2001). All these variables impact the frequency and severity of injuries such as deep cuts, broken bones, concussions, and other trauma that sometimes leads to death (Eidson et al., 1990). Structure stability is also a key risk determinant. Those who are in manufactured or mobile homes during a tornado have a 10-fold risk of death compared with those in permanent structures (Sutter and Simmons, 2010). In fact, one-third of all tornado fatalities occur in mobile homes. Among permanent structures, older homes, wooden structures, those not anchored to the foundation, and houses without basements are also high risk (Balluz et al., 2000). Those residing in permanent homes account for 25% of fatalities, and those in vehicles account for 13% (NOAA, 2009).

In addition to traumatic injuries, tornadoes sometimes bring less common public health threats. For example, there have been recent cases of invasive fungal infections associated with tornado victims. Following the 2011 Joplin tornado, a cluster of cutaneous mucormycosis cases were identified. This infection is caused by *Mucoromycotina*, a fungus typically found in soil, decaying leaves and wood (CDC, 2015). Thirteen individuals, who were all in the area of the most significant tornado damage, were affected and required antifungal therapy. These necrotizing soft-tissue infections are associated with high morbidity and mortality. Five of 13 (38%) patients died from their infection within 14 days of injury (Neblett et al., 2012). Healthcare providers treating victims of tornado-related trauma should maintain awareness of these and other possible nontraumatic health threats and the unique treatment challenges they can pose.

Recent research reveals even more subtle effects of thunderstorms. There is a growing body of literature indicating increases in asthma attacks after thunderstorms. Storms with

high winds and rain have been associated with a 3% rise in asthma-related emergency department visits (Grundstein et al., 2008). This increase is believed to be due to the rupture and release of pollen grains during the storms. Other meteorological factors contributing to the increase in asthma attacks include the number of lightning strikes, rainfall, drop in temperature, and a rise in air pressure and relative humidity (Celenza et al., 1996).

Public health and emergency management organizations should work closely together to communicate the health risks associated with severe storms and to raise public awareness through educational initiatives. Organized safety drills and preparedness exercises provide practice for individuals, families, and workplaces. These drills ideally should test public warning sirens and systems to ensure they are heard by those at home and at work. Many states promote these exercises and drills in recognition of Severe Weather Awareness Week and scheduled tornado drill days. These campaigns are typically scheduled just before the annual rise in severe weather threats in the early spring. Specific focus should be placed on vulnerable populations, such as the elderly and those with disabilities and/or functional support needs. In addition, planning should focus on populations living or working in mobile homes and other more damage susceptible structures. Prevention engineering, building codes, and storm shelters are essential in high-risk regions.

Prevention and Preparedness

Before a thunderstorm or tornado occurs, the essential preparedness activities described in the Community Preparedness section of chapter Public Health Preparedness Capabilities should be considered. Individuals and families should have a plan and a preparedness kit and should be prepared to follow the instructions of authorities. The plan should include both instructions on how to immediately react to an imminent storm threat and a communication plan detailing how to communicate with family or friends immediately after a storm. Communication plans should include contact information for family or friends out of the immediate area in the event family members become separated during a severe weather event. Preparedness kits must maintain sufficient quantities of essentials. A thunderstorm can take out critical utilities over a large area for days or even weeks. There is growing empirical evidence indicating family emergency preparedness planning increases the likelihood of individuals taking shelter upon receiving severe storm warnings and that this planning prepares communities for a variety of rapid onset disasters (Cong et al., 2014).

Emergency alert systems are rapidly evolving around the world. Receiving warnings from multiple sources increases the likelihood of the public taking appropriate protective actions. This is especially true in regions with a lower frequency of storms and lower awareness of severe storm safety. Emergency managers should focus efforts on these less-aware, more-vulnerable populations, when planning warning strategies (Luo et al., 2015). The public must be educated to recognize and react appropriately to dangerous weather conditions. When threatening weather is approaching, local radio and television are prominent partners in sharing warnings. Warning sirens are also key in communities taking

appropriate protective actions (Liu et al., 1996). These systems are essential in alerting a community of an impending threat. An NOAA weather radio is a useful addition to warning systems for homes and businesses. These radios have grown into all-hazards warning systems. Not only do they alert areas at risk for dangerous weather, but they are also used for environmental announcements such as chemical spills and public safety issues such as Amber and Silver Alerts for missing children or elderly individuals. These warning alerts are also widely available as smart phone applications offered by many wireless carriers, including wireless emergency alerts, which provides weather warnings. These systems are linked together across the United States by the Emergency Alert System, which replaced the U.S. Emergency Broadcast System in the early 1990s.

Similar alert systems exist around the world, including the telephone-based Emergency Alert (EA) Australia system, which has been under development since 2009. Testing indicates it is able to effectively reach greater than 80% of residents in a defined risk area using landline voice messages and cellphone text messages. An evaluation of the EA system found nearly 100% of recipients reported the messages were understood. However, deficiencies in community preparedness were noted, suggesting although the messages were clear, nearly one-quarter of the population did not understand the use of the EA system and nearly 30% were unprepared for an emergency (Torrens, 2011). This is a common gap. Emergency warning systems are critical, but their impact on public safety is dependent on individuals understanding what to do when they hear warnings and being willing to take the correct actions. The Australian government, like many others, continues to explore ways to enhance these systems, including the use of social media and focused strategies to alert those with disabilities and functional needs.

In the European Union (EU), an innovative system is evolving addressing challenges in delivering a rapid, concise emergency message across diverse languages, cultures, and government organizations. The Alert4All Project allows the appropriate civil protection authority (emergency manager) to describe a crisis using key words in the Alert4All system. The system automatically encodes a message about the emergency, the risks, and recommended actions. The system then pushes the messages out, through text and audio, in the language of those affected by the emergency. The messages are delivered on entertainment and communication devices, including digital TVs, computer tablets, smartphones, navigation systems, public monitors. and mass notification systems. The system then monitors social media for public comments and opinions on the alerts. This feedback provides officials critical information used to adjust messages according to public perceptions (EU, 2014). This multimodal delivery system, with built in social media feedback mechanisms, represents the future of public emergency alerts (Fig. 17-7).

There are simple things communities can do to reduce the risks associated with severe storms. The public should be educated to maintain awareness of anything that could fall during high winds, potentially causing damage or injury. Trees should be kept trimmed, particularly those near power lines, and dead trees and branches removed. Simple preparedness rules should be promoted. The 30/30 lightning safety rule is a good example. If lightning is seen and those observing it cannot count to 30 before hearing thunder, then they are within

FIGURE 17-7 Emergency alert system. *Photographs courtesy of the NOAA and the Federal Emergency Management Agency (FEMA).*

range of a lightning strike and should seek shelter and not remain in a vulnerable place. It is best to remain indoors in this situation. This level of risk applies until 30 minutes after the last rumble of thunder is heard (FEMA, 2015). Vulnerable locations include any tall, isolated trees, hilltops, open fields, the beach, and the water. Small structures in open areas are also susceptible. Anything metal, including bicycles, golf clubs, etc., should be avoided since they can attract lightning. Several myths prevail regarding lightning strikes. Rubber-soled shoes and rubber tires on vehicles do not offer protection. Although being in a car is safer than being in the open, it is still vulnerable to a lightning strike. However, it is dangerous to take a shower or bath during a storm as plumbing and bathroom fixtures can conduct electricity. This surge of energy from lightning can reach a person showering. If a community has prepared, receives a warning of an approaching severe storm, and takes appropriate action to shelter, their remaining vulnerability is determined by their building's structural integrity.

Buildings can be designed to better withstand the high winds of severe storms. To some extent, this includes tornadoes. In the United States, state and local governments can adopt and enforce provisions of building codes in areas more prone to severe storms. The International Building Code and the International Residential Code are two examples of model codes but there are others as well (Kiesling, 2013). There are building codes used for hurricane safety in coastal areas of the East Coast and Gulf of Mexico. They include reinforcement of openings like windows, skylights, entry doors, and garage doors; anchors or straps to stabilize chimneys; and enhanced connections between walls and roofs, and between walls and foundations (FEMA, 2010). However, there are no codes specific to tornadoes. Although applying the coastal code recommendations in tornado prone areas will reduce structural vulnerability overall, those standards alone are insufficient for tornadoes beyond an EF3 rating. "Safe rooms" or tornado shelters are the only places that provide adequate protection during a tornado.

The FEMA has guidance for constructing safe rooms. Residential safe rooms are designed into or added to homes to protect individuals and families. Community safe rooms can be either public or private for specific organizations and businesses. Safe rooms can be a "hardened" space inside an existing building or a separate, nearby structure (Fig. 17-8). A hardened room or building uses stronger building materials and specified designs resistant to both high winds and the impact of debris projectiles (FEMA, 2011). Detailed guidance on building safe rooms in residential and commercial buildings is available through FEMA.

FIGURE 17-8 Emergency Operations Center (EOC) in Tuscaloosa, AL, following the 2011 tornado. It serves as a good example of a hardened facility. They lost operations but the EOC remained intact even though the story above it collapsed. *Photograph by Tuscaloosa County Sheriff's Office.*

FIGURE 17-9 FEMA urban search and rescue specialist Mark Foster looks at a storm shelter used by residents in the 2013 Moore Tornado. The shelter was intact and all inside survived. *Photograph by Andrea Booher/FEMA.*

Nearly absolute protection can be provided by a tornado shelter (Fig. 17-9). In ground shelters provide the best protection but a variety of above ground shelters are also available. Proper selection of both a shelter and installer is critical. The tornado shelter industry is not regulated and there is no shortage of unfortunate customer stories.

Those investing in a shelter should ensure both the product and vendor carry a certification from a reputable organization such as the National Storm Shelter Association or the American Tornado Shelter Association.

Immediate Actions

An approaching thunderstorm carries risks of flooding, high winds, hail, lightning, and tornadoes. When a thunderstorm approaches, actions are dictated by individual circumstances. Outdoor activities and events should be canceled. Individuals indoors should take appropriate actions depending upon the type of structure (eg, evacuate a mobile home, shelter in a basement, seek safety in the innermost and lowest portion of a building). Persons in cars should drive appropriate to conditions. In the event of a tornado warning, persons in cars should leave their vehicle and seek shelter. Those who are in the water or on a boat should quickly get to dry land and seek shelter. Local government leaders and emergency managers should regularly remind the public of these and other basic protective actions. Messaging should include reinforcing the meaning of thunderstorm and tornado watches and warnings when they are announced.

Alerts, watches and warnings should include reminders of appropriate actions. These messages should be embedded in television and radio announcements, as well as voice and text warning messages. The basic messages are:

1. Do not try to outrun a tornado in a car.
2. Do not stay in a car or take shelter next to or under it.
3. Do not stay in a mobile or manufactured home.
4. If outside without shelter, stay away from trees, lie flat in a ditch or other low lying area and protect your head.
5. Underground tornado shelters or safe rooms offer the best protection.
6. If those are not available, take shelter indoors but avoid windows.
7. Seek shelter in the innermost space of the lowest floor.
8. Take cover in an interior bathroom, closet, hallway, or under stairs.
9. Cover yourself with something sturdy such as a large table and protect your head.
10. These actions also apply for those functionally disabled, such as those in a wheelchair. If unable to move from a chair or bed, cover up as much as possible with blankets, pillows, etc.

The best summary of these actions is provided by a US. National Weather Service campaign: “Get in, Get Down, and Cover Up!” (NOAA, 2012a,b).

Public emergency alerts should be issued promptly—and include all available delivery methods, including local sirens, radio and TV announcements, wireless emergency alerts, email, text message notifications, social media like Facebook and Twitter, and Reverse 911. Reverse 911 is a system in place in some regions of the United States that places calls to phone numbers in a specified geographical region with a prerecorded emergency warning message.

Personal protective equipment is not generally a consideration for safety from storm related injury. However, in a review of injuries resulting from the 2011 tornado outbreak in Alabama, there were three children, each with protective gear, directly exposed to an EF4 tornado who sustained minor injuries. One was wearing a helmet and two others were in infant car seats (Campbell et al., 2012). Although there is little empirical evidence helmets offer protection, it is clear many tornado fatalities result from head injuries. Using a helmet could offer added protection.

Although the initial physical and mental impact on the general population in the direct path of a storm can be severe, those first minutes and hours following a storm can have a disproportionate impact on first responders. Although many police, fire, and emergency medical services system professionals encounter human tragedy on a regular basis, it cannot prepare them for the scale of devastation that may result from a tornado. While responding to the overwhelming demands of an impacted community, responders' families and homes can be at risk as well. The effectiveness of the immediate actions taken by the response community will depend on personal and professional planning, training, and exercises.

As a tornado approached Joplin, MO, in 2011, warning sirens began to sound. An alert was sent throughout the hospital and staff began implementing their tornado evacuation plan. With several minutes of warning, staff quickly moved patients to lower and interior areas of the hospital. When it was over, five patients and one visitor were dead (Fig. 17-10). Given the severe damage inflicted on the building, it is miraculous there were so few casualties. More than 180 patients were saved. Staff members' emergency planning, training, and exercising were severely tested

FIGURE 17-10 The Intensive Care Unit at St. John's Regional Medical Center in Joplin, MO, after the 2011 EF-5 tornado struck the city. *Photograph by Elissa Jun/FEMA.*

Continued

—cont'd

FIGURE 17-11 Moore Medical Center destroyed in the 2013 Moore Tornado. *Photograph by George Armstrong/FEMA.*

and proved successful. One of the preparedness program leaders was the director of quality and risk management, Dennis Manley. He said the staff "knew exactly what [they] should be doing. All that drilling and education really does pay off" (Hobson, 2013).

A similar event occurred in 2013. Moore, OK, was hit by a powerful EF5 tornado. Lying directly in its path was Moore Medical Center, a small, 45-bed facility (Fig. 17-11). Through the glass doors and windows, staff could clearly see the tornado approaching. The hospital's tornado emergency plan was initiated, and all staff, along with 30 patients, moved to a first floor interior area void of windows. These staff and patients were quickly joined by nearly 300 area residents seeking shelter. Although the hospital was completely destroyed, there were no fatalities. The media reported they were "lucky". In reality, little luck was involved. The lack of fatalities was a direct result of preparedness planning, training, and exercising (NPR, 2013). The immediate actions taken were well planned and executed.

Response and Recovery

A variety of health risks result from thunderstorms and tornadoes, but the risks do not end when the storm passes. Managing postdisaster public health challenges is daunting. The enormous amount of debris, potential exposures to spilled chemicals, and lack of utilities can extend and exacerbate health risks for weeks or even months. Recovery is an arduous process and injuries become more likely as tension and frustration are combined with a hazardous environment.

Emergency preparedness planning sometimes overlooks debris management and associated health risks. Storm-related debris can pose multiple hazards. Debris can include construction and demolition materials, hazardous materials or chemicals, vegetative debris, automobiles, appliances, furniture, and an array of other miscellaneous materials and items. Incorporating planning for managing massive quantities of storm debris should be initiated prior to a disaster, include key stakeholders, and be regularly updated with other preparedness and response plans.

In order to protect public health, a temporary debris management site should be selected. The U.S. Environmental Protection Agency has published recommendations for site selection (EPA, 2008). The recovery process is more successfully coordinated and the resulting public health threats are better mitigated if site selection is accomplished well in advance of need. These recommendations include:

1. Adequate size with appropriate topography and soil type
2. Appropriate distance from potable water wells, rivers, lakes, and streams
3. Free from obstacles, such as power lines and pipelines
4. Located away from a floodplain or wetland area
5. Storm water runoff, erosion, fire, and dust mitigation measures in place
6. Limited public access with secure debris drop-off areas
7. Close to the impacted area
8. Far enough away from residences and businesses to ensure they are not affected
9. On public lands or
10. On private lands only if more convenient and logistically necessary (planned in advance)

Managing hazardous materials, including hazardous household waste, requires additional planning including site safety and evacuation plans, regular air monitoring, establishment of counting stations, and designated areas for gas cylinders, fire extinguishers, batteries, ammunition, as well as other specific areas to sort, characterize, and prepare materials for safe transfer. More information on chemical risks may be found in chapter Chemical Hazards and Disasters, Chemical Threats.

Residential and business cleanup activities also pose risks. Structures with major damage carry hazards of traumatic injury from collapse and debris. Hazardous chemical risks can be complicated by spilling and mixing. Vectors, such as rats, mice, and mosquitoes, can increase. In addition, habitable structures without utilities can pose threats including inappropriate indoor use of generators resulting in carbon monoxide poisoning. The lack of utilities also increases the risks of foodborne and waterborne illnesses.

The measures essential to reducing public health threats during recovery include community outreach and education, vaccinations, and mental health services. It is important to promote community health and safety messages throughout the recovery process. These messages should be delivered by as many means as possible including paper flyers, social media, print media, radio, and television. Topics include physical safety for those returning to damaged property, carbon monoxide hazards posed by generators, heat

stress, hazardous materials, fire, confined spaces with low oxygen or risk of entrapment, unsafe food and drinking water, personal hygiene, and vaccinations.

Tetanus shots must be made widely available to those exposed to debris. Tetanus is a serious infection caused by contamination of wounds from bacteria that live in the soil. It is not transmitted person to person. Tetanus can result in severe neurological problems including paralysis, breathing complications, and death. Puncture wounds, such as stepping on a nail, carry particular risk of wound contamination. The vaccination, tetanus, and diphtheria toxoids and acellular pertussis (Tdap) or the tetanus and diphtheria toxoids (Td) for those who received a Tdap vaccination 5 or more years earlier offers effective protection against the infection. In addition, if sheltering and other recovery activities result in crowded group settings, influenza, varicella, and MMR (measles, mumps, and rubella) vaccinations should be considered (CDC, 2014a). Vaccination program staff from local public health agencies should be involved in recovery activities to ensure appropriate, timely vaccination delivery.

The rapid, destructive nature of severe storms, especially tornadoes, poses exceptional challenges for mental health. Local behavioral health facilities can be damaged or quickly overwhelmed by community mental health needs. Response to a severe tornado usually requires rapid deployment of mental health professionals to support the community through the recovery period and beyond. It is important to assure proper training and credentialing of those offering care in order to reduce the risk of well-intentioned but unqualified volunteers offering poor or damaging support. Real mental health recovery goes beyond provision of care. The overall recovery of the community infrastructure, including reopening of businesses and schools, plays a major role in mental health. More details are provided in chapter Disaster Behavioral Health, Disaster Behavioral Health.

The 2011 Joplin, MO, tornado completely destroyed six of the 18 schools in their school district. An announcement was made by school superintendent C.J. Huff, just a couple days after the disaster, proclaiming schools would reopen as scheduled for the next school year. He said, "We did not want to lose our community; we did not want to lose our families. Schools are a big part of why people are in Joplin, and getting back to normal quickly was very important" (Sulzberger, 2011). It was an unlikely proposition. In addition to the six schools destroyed, others needed major repairs. Throughout the summer, the reopening of schools became a call to action for the community to return to normalcy. The community rallied and schools managed to open on time as promised. The celebration of the school openings signaled a collective step toward community healing (Fig. 17-12).

Summary

Thunderstorms and tornadoes pose an array of immediate- and long-term risks to health and safety. As with other natural disasters, basic community preparedness can make an

enormous difference in a storm's overall impact. Risk-based preparedness initiatives should focus on the regions and populations at greatest risk. In public outreach, mobile home parks should receive more attention in public awareness initiatives than those in sturdy structures with basements. Individuals with disabilities or functional support needs should also receive added emphasis in storm prevention awareness efforts. Schools and hospitals must maintain robust preparedness planning, staff training, and exercises. Effective severe weather preparedness requires a comprehensive, multidisciplinary, and multiagency approach.

FIGURE 17-12 Joplin High School was a total loss after an EF-5 tornado hit the city in May 2011. A new temporary facility was built at a local mall and ready for the new school year. *Photographs by Steve Zumwalt and Elissa Jun/FEMA.*

Similar priorities were recognized by a group of international experts who met at the Ministry of Health of the Slovak Republic in 2004 to discuss the public health response to severe weather events (WHO, 2004). The meeting was organized by the World Health Organization Regional Office for Europe and the European Environment Agency. Primary recommendations from the meeting include:

1. Shift from an emphasis on postdisaster intervention to predisaster planning.
2. Identify and protect vulnerable groups.
3. Meteorological agencies, health departments and civil protection agencies must work together to develop early warning, surveillance mechanisms, intervention plans, and crisis management tools.

Severe weather poses a problematic combination of threats and has a direct impact on public health and supporting community infrastructure. Diminished infrastructure impedes effective response (Fig. 17-13). Severe weather disasters are infrequent but potentially widespread and severe (Kanter and Abramson, 2014). The preparedness solution includes ongoing individual and community planning and awareness campaigns; multifaceted means of rapid public warnings; enhanced building codes; and promotion of safe rooms and shelters. Apathy, both in the general public and across response agencies, including public health, can result in an unprepared and vulnerable population. The lack of effective preparedness engagement can only be overcome through enhanced preparedness coordination across response organizations and constant community promotion of severe storm awareness.

FIGURE 17-13 Metal wrapped around a remaining tree in the tornado that devastated the community of Westmoore following the 2013 Moore Tornado. *Photograph by Andrea Booher/FEMA.*

Websites

American Red Cross, Thunderstorm Preparedness. http://www.redcross.org/prepare/disaster/thunderstorm.

American Red Cross, Tornado Preparedness. http://www.redcross.org/prepare/disaster/tornado.

Centers for Disease Control and Prevention, Lightning. http://www.bt.cdc.gov/disasters/lightning/.

Centers for Disease Control and Prevention, Preparing for a Tornado, Part 1. http://emergency.cdc.gov/disasters/tornadoes/prepared.asp.

Centers for Disease Control and Prevention, Preparing for a Tornado, Part 2. http://emergency.cdc.gov/disasters/tornadoes/prepared-page2.asp.

Centers for Disease Control and Prevention, Preventing Carbon Monoxide Poisoning after an Emergency. http://emergency.cdc.gov/disasters/cofacts.asp.

Environmental Protection Agency (EPA) Planning for Natural Disaster Debris. http://www.epa.gov/wastes/conserve/imr/cdm/pubs/pndd.pdf.

European Union, Alert4All. http://www.alert4all.eu/.

Federal Emergency Management Agency, Ready Campaign, Thunderstorms and Lightning. http://www.ready.gov/thunderstorms-lightning.

Federal Emergency Management Agency, Ready Campaign, Tornadoes. www.fema.gov/hazard/tornado/index.shtm.

Federal Emergency Management Agency, Recovery Advisories from the Tornado Mitigation Assessment Teams (MATs) for Alabama, Mississippi, Tennessee, Georgia, and Missouri, 2011. https://www.fema.gov/media-library/assets/documents/22024.

High Wind Safe Room Guidance. http://highwindsaferooms.org/.

Missouri Storm Aware Program. http://stormaware.mo.gov/.

National Institute for Occupational Safety and Health (NIOSH), Workplace Safety & Health Topics, Tornado Cleanup and Response. http://www.cdc.gov/niosh/topics/emres/tornado.html?s_cid=ccu060611_013.

National Oceanic and Atmospheric Administration, National Weather Service, NOAA Weather Radio. www.weather.gov/nwr/.

National Oceanic and Atmospheric Administration, National Weather Service, Thunderstorms, Tornadoes, Lightning, a Preparedness Guide, Including Tornado Safety Information for Schools. http://www.nws.noaa.gov/om/severeweather/resources/ttl6-10.pdf.

National Oceanic and Atmospheric Administration, National Weather Service, StormReady Program Site. www.stormready.noaa.gov/.

Texas State University, Texas School Safety Center, Tornado Severe Weather Guidance for Schools. http://txssc.txstate.edu/topics/emergency-management/articles/severe-weather-guidance.

Texas Tech University, National Wind Institute (NWI). http://www.depts.ttu.edu/nwi/.

References

Adekoya, N., Nolte, K., 2005. Struck-by-lightning deaths in the United States. J. Environ. Health 67 (9), 45–50.

Balluz, L., Schieve, L., Holmes, T., Kiezak, S., Malilay, J., 2000. Predictors for People's response to a tornado warning: Arkansas, 1 March 1997. Disasters 24 (1), 71–77.

Campbell, C.M., Baker, M.D., Monroe, K.W., 2012. Prevention of child injuries during tornadoes: cases from the 2011 tornado outbreak in Alabama. Pediatr. Emerg. Care 28 (12), 1389–1390.

Centers for Disease Control and Prevention (CDC), 1992. Tornado disaster–Kansas, 1991. MMWR 41, 181–183.

Celenza, A., Fothergill, J., Kupek, E., Shaw, R.J., 1996. Thunderstorm associated asthma: a detailed analysis of environmental factors. BMJ 312, 604.

Centers for Disease Control and Prevention (CDC), 2013. Number of deaths from lightning among males and females–national vital statistics system, United States, 1968–2010. MMWR 62 (28), 578.

Centers for Disease Control and Prevention (CDC), 2014a. Interim Immunization Recommendations for Individuals Displaced by a Disaster. Available at: http://emergency.cdc.gov/disasters/disease/vaccrecdisplaced.asp.

Centers for Disease Control and Prevention (CDC), 2014b. Lightning: Victim Data. Available at: http://emergency.cdc.gov/disasters/lightning/victimdata.asp.

Centers for Disease Control and Prevention (CDC), 2015. Fungal Diseases: Mucormycosis. Available at: http://www.cdc.gov/fungal/diseases/mucormycosis/.

Cong, Z., Liang, D., Luo, J., 2014. Family emergency preparedness plans in severe tornadoes. Am. J. Prev. Med. 46 (1), 89–93.

Cooper, M.A., 1980. Lightning injuries: prognostic signs for death. Ann. Emerg. Med. 9, 134–138.

Duclos, P.J., Sanderson, L.M., 1990. An epidemiological description of lightning-related deaths in the United States. Int. J. Epidemiol. 19, 673–679.

Eidson, M., Lybarger, J.A., Parsons, J.E., MacCormack, J.N., Freeman, J.I., 1990. Risk factors for tornado injuries. Int. J. Epidemiol. 19, 1051–1056.

Environmental Protection Agency (EPA), 2008. Planning for Natural Disaster Debris. Document ID Number EPA530-K-08-001. Available at: http://www.epa.gov/wastes/conserve/imr/cdm/pubs/pndd.pdf.

European Commission (EU), 2014. An Emergency Alert System for Europe. Horizons 2020. The EU Framework Programme for Research and Innovation. Available at: http://ec.europa.eu/programmes/horizon2020/en/news/emergency-alert-system-europe.

Federal Emergency Management Agency (FEMA), 2010. Wind Retrofit Guide for Residential Buildings. FEMA P-804. Available at: http://www.fema.gov/media-library-data/20130726-1753-25045-2304/508versioncombined_804.pdf.

Federal Emergency Management Agency (FEMA), 2011. Safe Rooms: Selecting Design Criteria, Tornado Recovery Advisory RA2. June 2011. Available at: http://www.fema.gov/media-library-data/20130726-1801-25045-2230/ra2_2011_storm_shelters_tagged_011912.pdf.

Federal Emergency Management Agency (FEMA), 2015. Before Thunderstorms & Lightning. Available at: http://m.fema.gov/before-thunderstorms-lightning.

Glass, R.I., Craven, R.B., Bregman, D.J., Stoll, B.J., Horowitz, N., Kerndt, P., Winkle, J., 1980. Injuries from the Wichita falls tornado: implications for prevention. Science 207, 734–738.

Grundstein, A., Sarnat, S.E., Klein, M., Shepherd, M., Naeher, L., Mote, T., Tolbert, P., 2008. Thunderstorm associated asthma in Atlanta, Georgia. Thorax 63, 659–660.

Hammer, B.O., Schmidlin, T.W., 2001. Vehicle-occupant deaths caused by tornadoes in the United States, 1900–1998. Environ. Hazards 2, 105–118.

Hobson, K., 2013. Hospitals Have Come a Long Way in Girding for Disaster. US News and World Report: Health. September 18, 2013. Available at: http://health.usnews.com/health-news/hospital-of-tomorrow/articles/2013/09/18/prepared-for-the-worst-hospitals-have-come-a-long-way-in-girding-for-disaster?page=2.

Holle, R.L., Lopez, R.E., Howard, K.W., Vavrek, J., Allsopp, J., 1995. Safety in the presence of lightning. Semin. Neurol. 15, 375–380.

Kanter, R.K., Abramson, D., 2014. School interventions after the Joplin tornado. Prehosp. Disaster Med. 29 (2), 214–217.

Kiesling, E., 2013. Testimony to the U.S. House of Representatives, Subcommittee on Technology Committee on Science, Space, and Technology. Hearing. June 5, 2013. Available at: http://docs.house.gov/meetings/SY/SY14/20130605/100941/HHRG-113-SY14-Wstate-KieslingE-20130605.pdf.

Krider, E.P., Uman, M.A., 1995. Cloud-to-ground lightning: mechanisms of damage and methods of protection. Semin. Neurol. 15, 227–232.

Liu, S., Quenemoen, L.E., Malilay, J., Noji, E., Sinks, T., Mendlein, J., 1996. Assessment of a severe weather warning system and disaster preparedness, Calhoun County, Alabama. Am. J. Public Health 1996 (86), 87–89.

Luo, J., Cong, Z., Liang, D., 2015. Number of warning information sources and decision making during tornadoes. Am. J. Prev. Med. 48 (3), 334–347.

Lopez, R.E., Holle, R.L., 1995. Demographics of lightning casualties. Semin. Neurol. 1995 (15), 286–295.

National Oceanic and Atmospheric Administration, National Weather Service, 2007. Enhanced F Scale for Tornado Damage. Available at: www.spc.noaa.gov/faq/tornado/ef-scale.html.

National Oceanic and Atmospheric Administration, National Severe Storms Laboratory, 2015a. Severe Weather 101, Thunderstorm Basics. Available at: http://www.nssl.noaa.gov/education/svrwx101/thunderstorms/.

National Oceanic and Atmospheric Administration, National Weather Service, 2015b. StormReady Program Site. Available at: www.stormready.noaa.gov/.

National Oceanic and Atmospheric Administration, National Weather Service, 2012a. Thunderstorms, Tornadoes, Lightning: Nature's Most Violent Storms—A Preparedness Guide. Available at: http://www.nws.noaa.gov/om/severeweather/resources/ttl6-10.pdf.

National Oceanic and Atmospheric Administration, National Weather Service, 2012b. Severe Weather: Tornado Safety. Available at: http://www.crh.noaa.gov/dmx/?n=preparesvrtorsafety.

National Oceanic and Atmospheric Administration, National Weather Service, 2015c. Lightning Science: Five Ways Lightning Strikes People. Available at: http://www.lightningsafety.noaa.gov/struck.htm.

National Oceanic and Atmospheric Administration, National Weather Service, 2009. Quickfacts: Tornadoes. Available at: http://www.crh.noaa.gov/Image/dvn/downloads/quickfacts_Tornadoes.pdf.

National Oceanic and Atmospheric Administration, National Weather Service, Office of Meteorology, 1996. Tornado Safety. National Oceanic and Atmospheric Administration, National Weather-Service, Washington, DC. Publication no. 1996-413-872.

National Public Radio (NPR), 2013. The Scramble at Moore Medical Center as the Tornado Hit. May 21, 2013. Available at: http://www.npr.org/blogs/health/2013/05/21/185826188/the-scramble-at-moore-medical-center-as-the-tornado-hit.

Neblett Fanfair, R., Benedict, K., Bos, J., Bennett, S.D., Lo, Y.C., Adebanjo, T., Etienne, K., Deak, E., Derado, G., Shieh, W.J., Drew, C., Zaki, S., Sugerman, D., Gade, L., Thompson, E.H., Sutton, D.A., Engelthaler, D.M., Schupp, J.M., Brandt, M.E., Harris, J.R., Lockhart, S.R., Turabelidze, G., Park, B.J., 2012. Necrotizing cutaneous mucormycosis after a tornado in Joplin, Missouri, in 2011. N. Engl. J. Med. 367 (23), 2214–2225.

Norton, S., June 18, 2011. The Will Norton Story Our Journey through the May 22nd Joplin Tornado. (Video file) Available at: https://www.youtube.com/watch?v=BVSeptS3kec.

Sheridan, M., May 29, 2011. Body of Will Norton, Joplin Teen 'Sucked Out' of SUV During Tornado, Found in Pond. New York Daily News. Available at: http://www.nydailynews.com/news/national/body-norton-joplin-teen-sucked-suv-tornado-found-pond-article-1.140504.

Sulzberger, A.G., August 17, 2011. Joplin Defies Odds, Just by Opening Schools. The New York Times. Available at: http://www.nytimes.com/2011/08/18/us/18joplin.html?pagewanted=all&_r=0.

Sutter, D., Simmons, K.M., 2010. Tornado fatalities and mobile homes in the United States. Nat. Hazards 53 (1), 125–137.

Torrens Resilience Institute, July 30, 2011. Assessment of the Effectiveness of Emergency Alert: Final Report. Available at: http://www.emergencyalert.gov.au/images/stories/Assessment_of_the_Effectiveness_of_Emergency_Alert_July_2011.pdf.

World Health Organization, February 9–10, 2004. Extreme Weather and Climate Events and Public Health Responses Report on a WHO meeting Bratislava, Slovakia. Available at: http://www.eird.org/isdr-biblio/PDF/Extreme%20weather%20and%20climate%20events.pdf.

18

Volcanoes

OBJECTIVES

- Define the Volcanic Explosivity Index (VEI).
- Describe the potential health effects of a volcanic eruption.
- List the morbidity and mortality effects of volcanic ash.
- Explain the health hazards associated with a pyroclastic flow.
- Define the health risks associated with laze.
- Explain what can be done to prepare for a volcanic eruption.
- Describe what individuals who are outside should do during a volcanic eruption.
- Explain the actions that should be taken by individuals indoors following a volcanic eruption.
- Describe the health and safety risks associated with ash accumulation and ways to reduce these risks.
- List the types of critical infrastructure damage which can result from an eruption and the public health threats posed.

Introduction: 1991 Eruption of Mount Pinatubo, Luzon Island, Philippines

Raul grew up in the shadow of Mount Pinatubo in the town of Baguio. After a 21-year career in the U.S. Air Force that had taken him around the world, he was looking forward to his retirement, ending his military career at Clark Air Base, Philippines. Soon he would be settling nearby into a new home he was building for his wife and three children. With his hometown so close, his family would finally get to spend more time with other family and friends and end the military moves and temporary duty assignments.

No one gave the risk of a Mount Pinatubo eruption much thought. The volcano lay dormant for so many centuries that an eruption was simply not discussed. As Mount Pinatubo became active and early warning signs emerged indicating an eruption could be approaching, the U.S. Air Force evacuated Clark Air Base. Small earthquakes began shaking the mountain throughout April and May. Several steam explosions emerged on the sides of the mountain. Even though Raul was doubtful much more would happen, he sent his family to stay with his in-laws as he stayed behind with several 100 airmen on the Air Base.

On June 12, 1991, Mount Pinatubo experienced one of the largest and most dramatic volcanic eruptions in recent history (Fig. 18-1). During the preceding week, magma slowly began to emerge and pool into a small lava dome. Then finally exploded in a catastrophic eruption, ejecting over a cubic mile (>4.2 km^3) of ash and debris, the top 1000 ft of the mountain, more than 20 miles into the sky. At the same time, pyroclastic flows of hot ash

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FIGURE 18-1 The 1991 Mount Pinatubo eruption taken from the east side of Clark Air Base. *Photograph by Dave Harlow, U.S. Geological Survey.*

and debris raced down the sides of the mountain and accumulated hundreds of feet deep in the surrounding valleys. Had it not been for the initial clues and the evacuation of thousands, the death toll would have been in the tens of thousands. The official death toll in the days following the eruption was just over 300 (Spence et al., 1991). The majority of these fatalities were attributed to structural collapses occurring under the tremendous weight of the accumulating ash on rooftops.

Raul's new home was not spared. As a major storm brought heavy rains to the area in the days following the eruption, the moisture met with the ash cloud, causing it to rain mud. His home was blanketed in layers of ash and mud. He shoveled 20 dump-truck loads of mud and debris from his home and began the painful task of rebuilding (Arana-Barradas, 2001; Newhall et al., 2005). The lush tropical vegetation across the region was buried and the terrain looked more like the surface of the moon. As years passed, the lush, green terrain returned, but the economy never fully recovered. The U.S. Air Force closed Clark Air Base and returned the property to the Philippine government. Although some uses have been found for major buildings left behind, the lives of the area residents and the local economy will never be the same. But despite the setbacks, many local residents, like the family of Filipino American and retired U.S. Air Force Technical Sergeant Raul Baon, have worked hard to rebuild the region.

Another eruption will happen someday. This is a fact of life everyone on the island lives with every day.

Volcano-Related Definitions

Acid rain Rain that becomes acidic as it falls through volcanic emissions. Acid rain can have a pH less than 4 and can cause environmental damage.

Ash (volcanic) Particle size applied to the finest pyroclastic material, fragments less than 1/8 in. (2 mm) in diameter, ejected into the air by volcanic explosions.

Ash cloud Fine volcanic material ejected into the air from a volcanic explosion or rising from a pyroclastic flow to form a cloud.

Ashfall (airfall) Volcanic ash and debris that falls from an eruption cloud.

Ballistic fragment Rock fragments that become projectiles as they are ejected from a volcanic explosion.

Cinder cone volcano Type of volcano formed when gas-filled lava is ejected into the air, breaking into small cinders and accumulating around the vent or vents (Fig. 18-2).

FIGURE 18-2 View of Pu'u 'O'o from the north shows the asymmetric shape of the cone. The prevailing trade winds blow from the northeast, so that most of the fallout from the high fountains lands on the downwind (right) side of the conduit. Kilauea volcano on the Hawaiian Islands displays both shield and cinder cone volcano structures. *Photograph by C. Heliker, U.S. Geological Survey.*

Composite volcano Also called a stratovolcano, it is a type of volcano that usually has a crater at the summit that has a vent or vents that erupt lava, cinders, and ash. This type of volcano poses substantial risks to surrounding residents and can produce pyroclastic flows and lahars (Fig. 18-3).

FIGURE 18-3 The May 18, 1980, Mount St. Helens eruption. *Photograph by Robert Krimmel, U.S. Geological Survey.*

Lahar Mass of volcanic debris mixed with water displaced from the volcano resulting in a mudslide of volcanic particles and fragments. It is also called a mudflow or debris flow.

Lateral blast Horizontal explosion from, or in the direction of, the side of a volcano.

Lava Molten rock or magma that reaches the earth's surface.

Lava dome volcano Type of volcano with a dome of lava forming around the volcano vent. The lava is less viscous resulting in it slowly accumulating around the vent. As it cools and hardens, it is cracked by internal pressure and fragments break free and accumulate around the dome (Fig. 18-4).

FIGURE 18-4 Mount St. Helens 2 years later with a small lava dome. *Photograph by Lyn Topinka, U.S. Geological Survey.*

Laze White plume of hydrochloric acid and vaporized seawater occurring when lava is combined with saltwater, causing a chemical reaction resulting in an acidic lava haze, or laze.

Magma Molten rock containing dissolved gases and minerals; called lava when it reaches the earth's surface.

N-95 respirator Air-purifying respirator that filters 95% of the particles from the air before the air is inhaled by the wearer.

Pyroclast The literal definition is "fire rock fragment." A pyroclast is simply a piece of material formed by a volcanic explosion or ejected from a volcanic vent.

Pyroclastic flow Extremely hot, fast-moving mixture of fragmented volcanic material and gas traveling at high speeds down the slope of a volcano. It is formed during an eruption or following the collapse of a lava dome.

Shield volcano Type of volcano composed of accumulated lava flows. Lava is slowly emitted from the volcano's vent(s). Shield volcano eruptions are typically nonexplosive (Fig. 18-5).

FIGURE 18-5 Kilauea eruption on the dawn of January 30, 1974, overflows from an active lava lake spilling down the flank of the volcanic shield at Mauna Ulu. Kilauea volcano on the Hawaiian Islands displays both shield and cinder cone volcano structures. *Photograph by Robert I. Tilling, U.S. Geological Survey.*

Silica Also called silicon dioxide (SiO_2), is composed of the elements silicon and oxygen, which comprise much of the earth's crust. Silica is generally seen in nature as sand. Silica may be of two forms: crystalline and noncrystalline. Crystalline refers to the fixed pattern of the molecules, such as quartz. Noncrystalline (amorphous) silica has a random molecular arrangement, such as diatomaceous earth. Respirable crystalline silica poses significant health threats.

Tephra The ash fall following a volcanic eruption that includes sand-sized or finer particles of volcanic rock and other fragments.

Volcanic explosivity index (VEI) A 0-to-8 index scale used to measure the intensity of a volcanic eruption. Each increase in number represents an increase of a factor of 10. It is based on several factors, including the estimated volume of erupted pyroclastic material, height of the eruption column, duration in hours, and additional qualitative descriptors.

Volcano Vent or opening in a planet's surface through which volcanic material is erupted.

Volcanoes

Volcanoes are responsible for the formation of much of the earth's surface. The origin of the word can be traced back to the Island of Vulcano, near Sicily. The island was named after Vulcanus, the Roman god of fire and the forge (metal working). Volcanoes are typically hills or mountains surrounding a vent leading to reservoirs of molten rock below the earth's surface. There are four primary types of volcanoes: Cinder Cone, Composite, Shield, and Lava Dome (USGS, 1997a). They each have distinct characteristics and are created by different types of eruptions. Nearly 10% of the world's population, over 500 million, lives in an area with a historical record of volcanic eruptions. This number will increase in the future due to the growth of densely populated cities near volcanoes (Doocy et al., 2013).

Levels of volcanic activity intensity are categorized by the Volcanic Explosivity Index (VEI) (Fig. 18-6). The VEI is a composite, semiquantitative estimate of a volcano's eruptive power. It includes quantitative measurements of variables such as the eruption cloud height and the

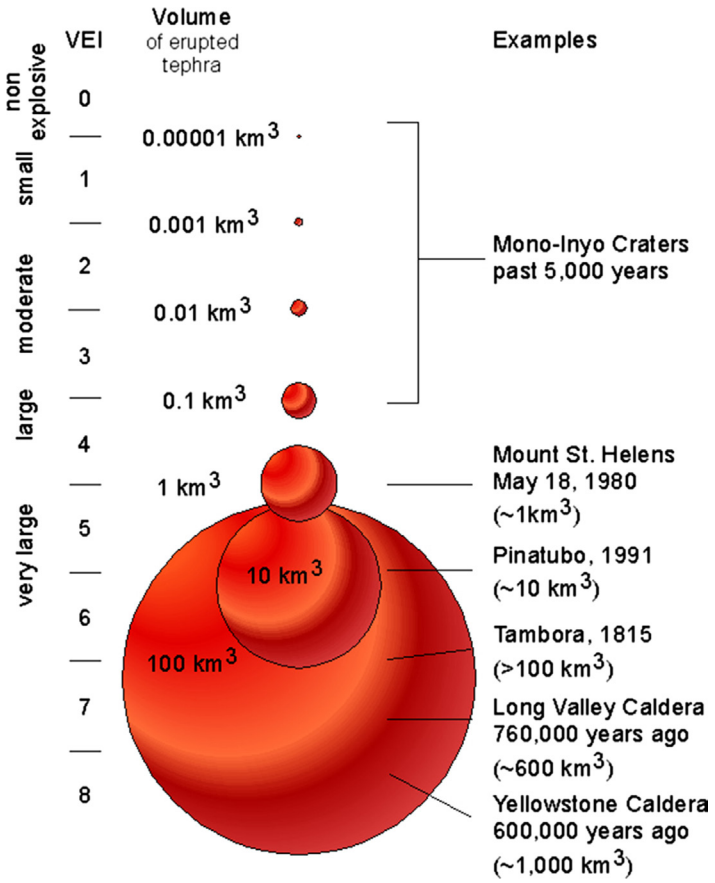

FIGURE 18-6 Volcanic explosivity index (VEI). *U.S. Geological Survey. Available at:* http://volcanoes.usgs.gov/images/pglossary/vei.php.

estimated amount of ejected material, including tephra and pyroclastic flow. The index combines those quantitative values with qualitative eruption observations to place the volcanic eruption on a scale from 0 to 8. Each increase in value of one represents a 10-fold increase in eruption intensity (Newhall and Self, 1982). The 10-fold increase with each number makes the measurement similar to the Richter scale used to measure earthquakes. It is estimated that over the past 10,000 years, there have been 4750 volcanic eruptions. The majority of these eruptions, nearly three-quarters (73%), have a VEI score of 2 (explosive), while 18% had a VEI 3 (severe) score, 6% were VEI 4 (cataclysmic), 2% were VEI 5 (paroxysmal), 1% was VEI 6 (colossal), and less than 0.1% had a VEI 7 (supercolossal) score (Simkin and Siebert, 1994). In recent history, from 1900 to 2014, there have only been 13 volcanic eruptions exceeding a VEI score of 4, including 10 VEI 5 and three VEI 6 eruptions (Table 18-1).

Table 18-1 Most Powerful Volcanoes, 1900–2014: VEIs of 5 (Paroxysmal) or 6 (Colossal)

Volcano	Location	Year	VEI
Puyehue-Cordón Caulle	Chile	2011	5
Mount Hudson	Chile	1991	5
Pinatubo	Luzon, Philippines	1991	6
El Chichon	Mexico	1982	5
Mount St. Helens	Washington, USA	1980	5
Mount Agung	Bali, Indonesia	1963	5
Bezymianny	Kamchatka, Russia	1955	5
Kharimkotan	Kuril islands, Russia	1933	5
Cerro Azul	Chile	1932	5
Colima	Mexico	1913	5
Novarupta	Alaska, USA	1912	6
Ksudach	Kamchatka, Russia	1907	5
Santa María	Guatemala	1902	6

Adapted from the Smithsonian Institution, National Museum of Natural History, Global Volcanism Program Database. Available at: http://www.volcano.si.edu/.

A volcanic eruption produces a variety of airborne health hazards. Enormous quantities of toxic gases and hazardous particles are rapidly ejected from a volcano. These gases are primarily comprised of water vapor, carbon dioxide (CO_2), and sulfur dioxide (SO_2), in addition to lesser volumes of other gases such as hydrogen sulfide (H_2S), hydrogen (H_2), carbon monoxide (CO), hydrogen chloride (HCl), hydrogen fluoride (HF), and helium (He) (USGS, 2010). These gases and particulates can quickly reach altitudes of 10–20 miles (15–30 km) and can be carried around the planet. Tephra particles immediately begin to fall out with large particles landing near the vent and smaller ones being carried downwind as a large cloud. The fine tephra ash covers everything causing the area immediately downwind from an eruption to appear as a lunar surface. As tephra material is being ejected upward, there are direct blasts and flows being projected laterally from the volcano as well. Large rocks and enormous volumes of materials can be expelled at a high rate of speed for many miles (FEMA, 2006). Pyroclastic flows can also form. These flows are composed of clouds of hot particles and gases

spilling down the slopes of a volcano (Fig. 18-7). Depending on conditions, these flows can travel several 100 miles per hour and consume everything in their path (USGS, 1997b). As the plume rises into the air, particles separate into layers of different charges, generating lightning similar to what is seen during thunderstorms. New emerging research suggests there is also a form of low-energy lightning generated from arcing particles emitted from a volcanic vent (Reilly, 2007). These particles could pose particular hazards to passing aircraft.

FIGURE 18-7 Pyroclastic flows descend the southeastern flank of Mayon Volcano, Philippines, 1984. *Photograph by C. Newhall, U.S. Geological Survey.*

As a volcanic eruption fills the air with toxic gases and particles, the downwind areas are covered with ash. In addition, significant lahars can occur. Lahars are flash floods or mudslides with heavy debris from a volcano (Fig. 18-8). These powerful floods can cause massive

FIGURE 18-8 Lahars from the 1985 Nevado del Ruiz volcano destroyed Armero, Colombia, killing three-quarters of the 28,700 inhabitants. *Photograph by N. Banks, U.S. Geological Survey.*

destruction for many miles leaving behind large volumes of sediment. Volcanic debris increases the destructive power of the flooding and complicates the cleanup efforts during recovery.

Human Health Effects

There are a variety of health hazards produced by volcanic activity. Some are direct hazards such as the rocks, ash, gases, and heat from a volcanic eruption. Larger solid debris, which can be projected for miles, can cause ballistic injuries, whereas gases can cause respiratory damage. Thermal injuries can result from exposure to pyroclastic or lava flows. Carbon dioxide gas and fine ash debris can cause asphyxiation. Other hazards result from secondary events triggered by a volcano, including earthquakes, flooding, landslides, lightning, and even tsunamis. The risks posed by an eruption are unique to each volcano and to each surrounding community. Some volcanoes will pose more acute threats from an explosive eruption, while others pose more chronic health risks from effusive eruptions with ongoing gas emissions. The type of volcano, geological composition, distance from the eruption, weather patterns, topography, and preexisting health status of the exposed populations are important factors in the morbidity and mortality related to a volcanic eruption.

The volcanic ash or tephra is comprised of very small rock and glass particles. It is typically gray with a consistency ranging from sand to fine powder (Fig. 18-9). Unlike ash from wood or paper product combustion, tephra is not water soluble. It is hard, abrasive, and acidic. Tephra particles that are less than 2 mm (1/12 in.) can be carried hundreds of miles downwind from a volcanic eruption and cause illness and injury through inhalational, mucosal, and dermal exposure. The abrasive ash particles can cause eye discomfort, pain, and itching accompanied by tearing or a sticky discharge. Corneal scratches, or abrasions, as well as acute conjunctivitis, are also common. In addition, tephra can cause respiratory damage. The severity of inhalational injuries depends upon the duration of exposure, the dose received, and the physical and chemical characteristics of the tephra (USGS, 2009). The distinct characteristics of tephra can vary significantly between eruptions making the risks difficult to estimate. The most common health effects include acute asthma and

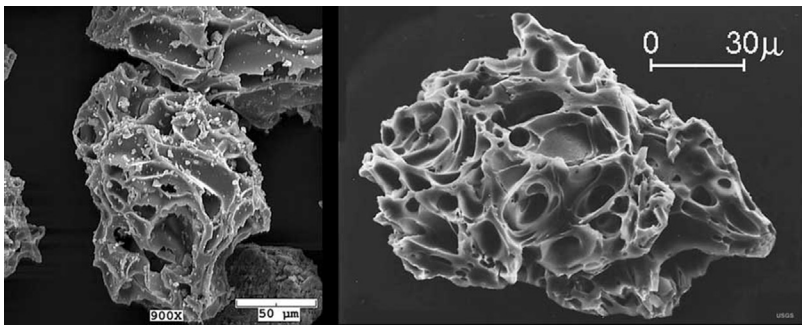

FIGURE 18-9 Electron microscope images of an ash particle from the 1980 Mount St. Helens eruption, magnified 200 times. *Photograph by U.S. Geological Survey.*

bronchitis and the exacerbation of chronic cardiac and respiratory diseases. Long-term illnesses are relatively rare (Gudmundsson, 2011).

Volcanic Ash Exposure, Common Acute Respiratory Symptoms (Blong, 1984)

- Nasal irritation and discharge
- Throat irritation and dry cough
- Airway irritation with coughing, wheezing, and/or shortness of breath
- Dyspnea
- Exacerbation of preexisting respiratory conditions

FIGURE 18-10 Sun seen through sulfur dioxide fume cloud at the summit of Kilauea, Hawaii, in 1985. *Photograph by J.D. Griggs, U.S. Geological Survey.*

Silica is the primary respiratory threat posed by tephra. Although the silica content can be high in volcanic ash, it is the respirable fraction of free silica that determines the risk, not the total silica volume. The presence of respirable crystalline silica (RCS) in the particles can pose both acute and long-term risks. Toxicity depends on the inherent characteristics and the surface chemistry of the silica (Horwell et al., 2012). Smaller silica particles travel deeper into the lungs, and the acidity of the particles creates an immediate irritant effect. Acute silicosis inflames the lungs and causes an accumulation of fluid. Symptoms include decreased oxygen saturation levels, shortness of breath, cough, fever, and weight loss. Inhalation of the ash can cause respiratory distress and extended exposures can cause fibrogenic pulmonary effects (Nicol et al., 1985). These problems are more likely to occur in individuals with preexisting conditions such as asthma,

bronchitis, and emphysema. Infants, the elderly, and those with chronic cardiovascular and respiratory conditions are at increased risk of morbidity following a volcanic eruption (WADOH, 2008).

Although rare, long-term illnesses are possible for people who experience large ash exposures over many years. Scarring and fibrotic nodules can develop around trapped particles as silica accumulates in the exposed lung tissue. As lung function declines, it is referred to as a condition called silicosis (SSDC, 1988). As the nodules enlarge, lung capacity decreases and breathing becomes increasingly difficult. This condition is incurable and can lead to death. Silicosis victims also have increased risk of other respiratory diseases, including tuberculosis (Bailey et al., 1974; Myers et al., 1973).

Like ash hazards, gas, fume, and acid particle hazards vary greatly between volcanic eruptions and impact vulnerable populations more severely than others (Fig. 18-10). Gases contained in molten rock are under tremendous pressure. As the magma reaches the surface, the gases under pressure rapidly expand and erupt in an explosive display. This eruption creates the tephra particles mixed with acid aerosols, making the volcanic ash acidic.

If 1 m^3 of magma containing 5% water is brought from below the earth's surface, where it is under extreme pressure, to atmospheric pressure, it will expand to nearly 700 times the original volume. This original 1 m^3 becomes about 670 m^3 of water vapor, gases, and particulates. This is the primary force behind explosive volcanic eruptions (Sparks et al., 1997).

Most volcanic gases released during an eruption are composed of water vapor, carbon dioxide, and sulfur dioxide. Relatively small amounts of hydrogen, hydrogen chloride, hydrogen fluoride, and hydrogen sulfide are also contained in volcanic gases. Of the gases listed, those that pose the most significant health risks are sulfur dioxide, carbon dioxide, hydrogen chloride, and hydrogen fluoride. Sulfur dioxide forms sulfuric acid when it comes in contact with mucous membranes causing inflammation and irritation of the eyes and respiratory tract. It is especially dangerous for those with preexisting pulmonary or cardiac conditions (Komarnisky et al., 2003). Carbon dioxide displaces oxygen and is an asphyxiant at high concentrations. It is heavier than air, and during a major release, dangerous levels can accumulate in low-lying areas (USGS, 2010). Like sulfur dioxide, hydrogen chloride and hydrogen fluoride are corrosive gases that become acids when in contact with mucous membranes (CDC, 2013; ATSDR, 2014).

Secondary chemical releases can also be generated during a volcanic eruption. For example, laze is a hydrochloric acid mist resulting from lava coming in contact with seawater. When lava enters seawater, the water vaporizes causing a series of chemical reactions to occur, emitting a white plume consisting of hydrochloric acid and seawater (USGS, 2010). This plume is called lava haze, or laze.

Following an eruption, falling ash can have a serious impact on critical infrastructure. Power supplies can be interrupted by ash accumulation on trees, breaking branches that fall on power lines. Ash accumulation directly on the power lines can also lead to breaks. Power facilities may be taken off line by ash blocking air intakes and other facility systems. Wet ash poses particular hazards. When fine ash becomes wet, it is an effective electrical conductor. Accumulation of wet ash can result in insulator flashover, taking down power systems (Fig. 18-11). Electrical conduction through wet ash poses safety risks for cleanup and power restoration responders. The loss of power can have a serious impact on area residents dependent on home medical devices or other critical equipment. Essential public health messages can be difficult to deliver without power for phones, radios, and televisions.

FIGURE 18-11 Ash-covered electrical-generating facility at former Clark Air Base in the Philippines following the 1991 Mount Pinatubo eruption in 1991. *Photograph by W.E. Scott, U.S. Geological Survey.*

Transportation infrastructure is easily disrupted by falling ash and resultant accumulations. Falling ash reduces visibility, obscures road signs, and creates perilous driving conditions. Accumulation of ash on roadways reduces traction and can make roads impassable. The falling ash is sometimes so thick even brake and tail lights are not visible. This was the case following the 1980 eruption of Mount St. Helens in Washington. About 75 miles (120 km) away from the eruption, several centimeters of ash accumulated on the roads, resulting in hundreds of motor vehicle accidents. A first-hand account of the situation was reported in a May 28, 1980, newspaper article appearing in the *Seattle–Post Intelligencer:*

Table 18-2 Critical Infrastructure Damage and Destruction from Volcanic Ash

Infrastructure	Effects
Agriculture sector	• Plant damage by ash weight • Plant damage by acid rain • Microphyte or microalgae destruction • Soil fertility reduction • Grazing livestock poisoning from soluble fluoride in ash • Livestock evacuation from environmental risks
Communications sector	• Equipment corrosion and damage • Power loss • Capacity overload from high demand • First responder communication loss (police, fire, EMS)
Energy sector	• Electrical safety risks • Downed power lines • Power facility interruption • Insulator flashover • Controlled outages for cleaning
Transportation sector	• Road closures
• Roads	• Reduced visibility from falling or resuspended ash • Reduced traction, especially with wet ash • Damage to vehicle engines
• Airports	• Airport closure • Aircraft engine damage • Damage or obstruction of runway lighting • Runway obstructions
• Railways	• Rail closures • Reduced visibility from falling ash • Damage to train engines and parts • Electrical short circuiting of trains and track signals
• Marine	• Port closures • Reduced visibility from falling ash • Damage to ship mechanical equipment • Ship channel obstruction (pumice rafts)
Healthcare, commercial, and government facilities, and housing sectors	• Structural damage or collapse from ash accumulation • Heating, ventilation, and air conditioning system clogging and damage • Gutters and drains clogging and damaged • Critical medical equipment power loss • Interior damage to appliances and electronics
Water and wastewater sector	• Water turbidity • Leaching of soluble components into water • Change in water pH and microbiology • Poor sanitation from potable water shortages • Treatment plant damage • Pipe blockages • Waterway damming or beaching • Damage to exposed electrical/mechanical system • Pump damage • Interference with treatment processes • Disruption of biological media processes

Adapted from USGS Volcano Hazards Program site: http://volcanoes.usgs.gov/ash/ and Wilson et al., 2014.

> *Brake lights could be faintly seen through the dust which rose 30 ft (9 m) above the freeway. Often, though, lights could not be seen, and all that could be heard was the tinkle of broken glass and the crunch of crumpled metal as cars from the rear headed into the ash clouds, and rammed vehicles already hidden in the clouds.*

Other infrastructure, including the drinking water supply and wastewater treatment, can be compromised. Drinking water from open reservoirs can experience heavy ash contamination. Management of the contamination can be difficult if existing infrastructure is also compromised. Widespread water supply contamination is possible during cleanup and can lead to shortages. Wastewater systems are also vulnerable. Both sewage and stormwater systems can become clogged as wet ash accumulates, becoming heavy mud in the system. This accumulation can also compromise pumping systems and other machinery. The critical infrastructure damage resulting from volcanic ash can have a substantial direct and indirect impact on morbidity and mortality (Table 18-2).

Prevention and Preparedness

Like many natural disaster hazards, preparedness measures for volcanoes begin with a home preparedness kit, plans for evacuation and communication, and understanding the associated risks. Unlike many other natural disaster threats that focus tightly on specific geographic regions, direct volcanic health threats can reach hundreds of miles/kilometers. Severe critical infrastructure damage poses added health threats. Preparedness efforts should focus both on individual/family preparedness activities, as well as community hazard mitigation strategies.

Residents of hazard zones should develop detailed emergency communication and family reunification plans. As previously discussed, personal preparedness kits should be maintained but should also include respiratory and eye protection, as well as sturdy shoes or work boots. Respiratory protection should include N-95 respirators, air-purifying respirators. These are fitted, high-quality masks that offer much better protection than typical dust masks. Clothing to cover all exposed skin should be prepared as well. Public education campaigns should include the specific types of warning and communication systems used before, during, and after an eruption. Volcanic eruption risk awareness should be supplemented by preventive actions associated with regional risks including earthquakes, tsunamis, landslides, and wildfires.

Suggested content for community preparedness messages for use prior to a volcanic eruption

- Be familiar with local and regional volcano threats, both active and dormant.
- Understand local plans and recommendations for preparedness.

- Establish an emergency kit. It should include an emergency supply of food, water, and other essentials, such as goggles and respiratory protection.
- Develop an emergency communication plan with family members.
- Stay away from active volcano sites.
- Plan evacuation routes away from low-lying areas and those prone to flooding.
- Monitor social media, television, and radio; ensure battery-powered backup for electrical devices and those requiring battery charging.
- Evacuate immediately if instructed by authorities.
- Assist vulnerable neighbors who may not be able to prepare or evacuate.
- Understand how to shelter safely in place if evacuation is not an option.
  Adapted from various sources, including the American Red Cross, Federal Emergency Management Agency, and Washington State Department of Health.

Throughout history, volcanoes have been fundamentally unpredictable. However, volcanoes are controlled by physical laws that can be studied, explained, and used for predictions and warnings. In recent decades, the understanding of volcanic processes has accelerated as eruptions are exhaustively studied by interdisciplinary teams (Newhall, 2000). Satellite imagery is able to observe tilting and deformation of a volcano not visible on at ground level. Broadband seismology is providing sharper, clearer seismic data. Volcanic gas monitoring is becoming more effective using improved field spectrometers. All these advances are working together to improve the ability to predict the type and timing of eruptions (Sparks, 2003). Given the unusually high ratio of fatalities to injuries near volcanic eruptions, evacuation is the primary protective measure. As technology improves, so does the ability of volcanologists and other scientists to evaluate risks, predict imminent eruptions, and recommend timely warnings and evacuation announcements. The growing effectiveness of these systems was demonstrated in the eruptions of Mount St. Helens and Mount Pinatubo. Scientific data were used to determine the timing and type of early warnings, which led to population evacuation and first responder community engagement (Doocy et al., 2013). The actions taken with these warnings reduced overall morbidity and mortality in both instances.

Immediate Actions

Initial actions taken during a volcanic eruption depend upon proximity to the eruption, ability to evacuate, and availability of shelter. Ideally, an order should be given to evacuate everyone at risk for exposure to blast debris, heated gases and lava flow. Whenever possible, evacuation routes should avoid areas downwind and low lying areas or river valleys downstream from the volcano. Public evacuation instructions should include landslide, mudflow and ash warnings. Examples of these warnings include avoiding bridges impacted by mudflows, driving slowly in ash fall, and avoiding driving in heavy ash fall (Fig. 18-12).

FIGURE 18-12 Volcanic ash falls to ground and creates darkness following the 1991 eruption of Mount Pinatubo in the Philippines. *Photograph by E. Wolfe, U.S. Geological Survey.*

Those unable to evacuate should be instructed to take shelter indoors and monitor radio or other media for more information. All doors and windows should be closed and ventilation systems shut down to limit ash intrusion into buildings. Electronic devices, indoors and outdoors, should be covered or wrapped in plastic to protect against ash exposure. Individuals sheltering should be instructed to stay in place until ash fall ends. The only exception to sheltering in place is when there is a risk of roof collapse from excessive ash accumulation. Indoor sheltering is also applicable to livestock and machinery. Livestock should be sheltered in barns or other buildings when possible to reduce exposure to gases and chemicals in ash. Vehicles and farm machinery should be placed inside a garage or barn to reduce potential damage caused by ash accumulation.

Instructions for venturing outside the shelter during ash fall include.

- Wearing long pants and long sleeve shirts, covering all exposed skin;
- Using goggles for eye protection and an N-95 or other protective mask for respiratory protection; and.
- Limiting time outdoors to a minimum to check on the risk of roof collapse or to help neighbors who may need assistance, such as the elderly or disabled (CDC, 2012).

Response and Recovery

Once an eruption occurs, the primary threat to public health and safety is volcanic ash. This includes direct threats posed to health as previously described in this chapter, as well as secondary risks. These risks include structural collapse from excessive ash accumulation, traffic accidents due to poor visibility or slippery roadway ash conditions, and health and safety hazards resulting from critical infrastructure damage. Access to basic hygiene,

safe food, and potable drinking water may be limited due to damaged water and wastewater systems and lack of power. Power interruptions can also constrain healthcare provision. Access to medical care can be hindered by transportation interruptions limiting the ability of first responders to transport patients, patient's ability to self-transport, and healthcare providers' ability to report to work.

The ash fall from a volcano is heavy and accumulations on a roof can lead to collapse. The only time it should be cleared while ash is still falling is if it poses a risk for roof collapse. Collapse risk generally exists when the ash accumulation approaches 4 in. Clearing the ash from the roof should be done carefully as the ash will pose a slipping hazard. Protective clothing, such as goggles and even minimal respiratory protection, will limit physical abilities. All exposed skin should be covered and goggles should be worn when clearing the roof of ash accumulation. Outer clothing should be removed before reentering the building to limit the transfer of ash into the structure.

Ash cleanup is a long, arduous process. Removal poses unique public health and critical infrastructure challenges. For example, roof ash removal is an important first step but care must be exercised to avoid physical injury while also limiting excessive ash deposits into sewage and stormwater systems. Cleanup at the home and community level must be planned and prioritized in advance. Large quantities of ash usually need to be hauled away from affected cities or villages to designated disposal locations. Ash disposal locations should be close to cleanup areas with access for heavy vehicles from a main road. The locations must consider proximity to surface water sources and ensure contamination prevention measures are in place (Johnston and Becker, 2001). Ash dispersion from wind can be mitigated by covering it with a layer of gravel, soil, or mulch. Long-term site management can include planting vegetation (Mayer, 1984). Long-term recovery may be hampered by persistence of contaminants in soil and water. There are limited studies of the long-term effects; however, findings of elevated trace elements in fish (Deheyn et al., 2005) and dissolvable and nondissolvable fluoride salts in water (Vaselli et al., 2006) have implications on direct and indirect food chain contamination. Further studies of downwind affects need to be conducted to ensure re-population health and safety.

Volcano ash management messages

- Keep the roof clear of ash accumulations of more than 4 in.
- Do not go outside while ash is falling unless it is to clear the roof to avoid collapse.
- Those with respiratory conditions, such as asthma or bronchitis, should avoid exposure.
- Individuals not directly involved in cleanup activities should remain indoors and close windows, doors, dampers, etc.
- Heating, ventilation, and air conditioning (HVAC) system filters should be cleaned or replaced often.
- Respiratory protection, such as N-95 respirators, should be used during cleanup activities.
- Eye protection, such as goggles, should be used and contact lens use avoided.

- Skin protection should include wearing long sleeves and long pants; removing outer clothing before entering the building.
- Travel should be minimized to avoid accident risks and vehicle damage; frequently change oil and air filters.
- Contaminated food or water should be avoided; use bottled or stored water; wash garden vegetables before eating.
  Adapted from Washington State Department of Health, Volcano Preparedness Guidance (2008).

Summary

Volcanoes are one of the most powerful and destructive forces on the planet, and they pose serious health and safety risks to those residing near them. Effusive eruptions release lava, fumes, and gases over time. Explosive eruptions can cause massive destruction from pyroclastic flows, ballistic projection of materials, thermal hazards, dangerous gases, and subsequent mud flows and ash fall. Fortunately, volcanologists have made substantial advancements in understanding and predicting eruptions. These advances have saved thousands of lives in recent eruptions and will save many more in the future.

Volcano-related morbidity and mortality can be reduced by advanced planning for community warning, evacuation and recovery and by promoting and reinforcing the basic messages of individual and family preparedness. Communities at risk must be educated to understand the nature and severity of volcano-associated hazards and appropriate protective measures to consider during evacuation, as well as during sheltering in place. The ongoing hazards associated with recovery operations can be mitigated by prioritized critical infrastructure restoration, effective public information sharing, precise technical advice, and careful attention to vulnerable populations.

Websites

Alaska Department of Health and Social Services, Health Effects Associated with Volcanic Eruptions. www.epi.hss.state.ak.us/bulletins/docs/b2006_05.pdf.

Alaska Volcano Observatory. http://www.avo.alaska.edu/.

American Red Cross, Volcano Preparedness. http://www.redcross.org/prepare/disaster/volcano.

Centers for Disease Control and Prevention, Emergency Preparedness and Response, Volcanoes. www.bt.cdc.gov/disasters/volcanoes/.

Dartmouth College, The Electronic Volcano, Volcano Study Resources. www.dartmouth.edu/~volcano/.

Durham University, Institute of Hazard, Risk and Resilience. https://www.dur.ac.uk/ihrr/.

Environmental Protection Agency (EPA), Volcanoes. http://epa.gov/naturaldisasters/volcanoes.html.

Federal Emergency Management Agency (Readygov), Volcano Preparedness. http://www.ready.gov/volcanoes/.

International Volcanic Health Hazard Network (IVHHN). http://www.ivhhn.org/.

International Volcanic Health Hazard Network (IVHHN), The Health Hazards of Volcanic Ash: A Guide for the General Public (English, French, Spanish, Portuguese, Japanese, Swahili, Icelandic and Bahasa Indonesia). http://www.ivhhn.org/images/pamphlets/Health_Guidelines_English_WEB.pdf.

Oregon State, Volcano World, Teaching and Learning Resources. http://volcano.oregonstate.edu/.

Smithsonian National Museum of Natural History, Global Volcanism Program. http://www.volcano.si.edu/.

U.S. Geological Survey, Volcano Ash. http://volcanoes.usgs.gov/ash/.

U.S. Geological Survey, Volcano Hazards Program. http://volcanoes.usgs.gov/.

U.S. Geological Survey, Hawaiian Volcano Observatory. http://hvo.wr.usgs.gov/.

University of Hawaii, The Center for the Study of Active Volcanoes. http://www.hilo.hawaii.edu/~csav/.

University of Tokyo, Volcano Research Center. http://hakone.eri.u-tokyo.ac.jp/vrc/links/links.html.

Washington State Department of Health, Emergency Preparedness and Response, Volcanoes. http://www.doh.wa.gov/Emergencies/EmergencyPreparednessandResponse/Factsheets/Volcanoes.

Washington State Emergency Management Division, Volcano. http://mil.wa.gov/emergency-management-division/hazards/volcano.

References

Agency for Toxic Substances and Disease Registry (ATSDR), 2014. ToxFAQs for Hydrogen Chloride. Available at: http://www.atsdr.cdc.gov/toxfaqs/tfacts173.pdf.

Arana-Barradas, L.A., November 1, 2001. Out of the Ashes: After Mount Pinatubo Nearly Buried it, Air Base Bounced Back. Airman.

Bailey, W.C., Brown, M., Buechner, H.A., Weill, H., Ichinose, H., Ziskind, M., 1974. Silico-mycobacterial disease in sandblasters. Am. Rev. Respir. Dis. 110, 115–125.

Blong, R.J., 1984. Volcanic Hazards: A Sourcebook on the Effects of Eruptions. Academic Press, Sydney, Australia.

Centers for Disease Control and Prevention (CDC), 2013. Facts about Hydrogen Fluoride (Hydrofluoric Acid). Available at: http://www.bt.cdc.gov/agent/hydrofluoricacid/basics/facts.asp.

Centers for Disease Control and Prevention (CDC), 2012. Emergency Preparedness and Response, Volcanoes. Available at: http://emergency.cdc.gov/disasters/volcanoes/index.asp.

Deheyn, D.D., Gendreau, P., Baldwin, R.J., Latz, M.I., 2005. Evidnece for enhanced bioavailability of trace elements in the marine ecosystem of Deception island, a volcano in Antarctica. Mar. Env. Res. 60 (1), 1–33.

Doocy, S., Daniels, A., Dooling, S., Gorokhovich, Y., April 16, 2013. The human impact of volcanoes: a historical review of events 1900–2009 and systematic literature review. PLOS Curr. Disasters. http://dx.doi.org/10.1371/currents.dis.841859091a706efebf8a30f4ed7a1901 Edition 1.

Federal Emergency Management Agency (FEMA), 2006. Disaster Information, Volcano. Available at: www.fema.gov/hazard/volcano/index.shtm.

Gudmundsson, G., 2011. Respiratory health effects of volcanic ash with special reference to Iceland. A review. Clin. Respir. J. 5 (1), 2–9.

Horwell, C.J., Williamson, B.J., Donaldson, K., Le Blond, J.S., Damby, D.E., Bowen, L., 2012. The structure of volcanic cristobalite in relation to its toxicity; relevance for the variable crystalline silica hazard. Part Fibre Toxicol. 19 (9), 44.

Johnston, D., Becker, J., 2001. Volcanic Ash Review – Part 1, Impacts on Lifelines Services and Collection/Disposal Sites. Auckland Regional Council Technical Publication. No. 144. 50 p.

Komarnisky, L.A., Christopherson, R.J., Basu, T.K., 2003. Sulfur: its clinical and toxilogical aspects. Nutrition 19 (1), 54–61.

Mayer, W.H., 1984. Federal Emergency Management Agency (FEMA), Region X. The Mitigation of Ashfall Damage to Public Facilities: Lessons Learned from the 1980 Eruption of Mount St. Helens, Washington. 70 p.

Myers, C.E., Hayden, C., Morgan, J., March 1973. Clinical experience with silicotuberculosis. Penn Med. 60–62.

Newhall, C., Hendley, J.W., Stauffer, P.H., 2005. The Cataclysmic 1991 Eruption of Mount Pinatubo. Philippines. U.S. Geological Survey Fact Sheet 113–97. http://pubs.usgs.gov/fs/1997/fs113–97/.

Newhall, C.G., 2000. Volcano warnings. In: Sigurdsson, H. (Ed.), Encyclopedia of Volcanoes. Academic Press, New York, pp. 1185–1197 (Chief Ed.).

Newhall, C.G., Self, S., 1982. The volcanic explosivity index (VEI)—an estimate of explosive magnitude for historical volcanism. J. Geophys. Res. 87 (C2), 1231–1238.

Nicol, E.R., Lee, E.S., Murrow, P.J., 1985. Respirable crystalline silica in ash erupted from Galunggung volcano, Indonesia, 1982. Atmos. Environ. 9 (7), 1027–1028.

Reilly, M., February 23, 2007. Erupting volcano crackles with low-energy lightning. New Sci. www.newscientist.com/article/dn11250-erupting-volcano-crackles-with-lowenergy-lightning.html.

Silicosis and Silicate Disease Committee (SSDC), 1988. Diseases associated with exposure to silica and nonfibrous silicate minerals. Arch. Pathol. Lab. Med. 112, 673–720.

Simkin, T., Siebert, L., 1994. Volcanoes of the World – A Regional Directory, Gazetteer, and Chronology of Volcanism during the Last 10,000 Years. Geoscience Press, Inc., Tuscon, p. 349.

Sparks, R.S.J., 2003. Forecasting volcanic eruptions. Earth Planet. Sci. Lett. 210 (1–2), 1–15.

Sparks, R.S.J., Bursik, M.I., Carey, S.N., et al., 1997. Volcanic Plumes. Wiley, New York, p. 574.

Spence, R.J.S., Pomonis, A., Baxter, P.J., Coburn, A.W., White, M., Dayrit, M., 1991. Building Damage Caused by the Mount Pinatubo Eruption of June 15, 1991. http://pubs.usgs.gov/pinatubo/spence/index.html.

U.S. Geological Survey, 1997a. Principal Types of Volcanoes. http://pubs.usgs.gov/gip/volc/types.html.

U.S. Geological Survey, 1997b. Pyroclastic Flows. http://pubs.usgs.gov/gip/msh//pyroclastic.html.

U.S. Geological Survey (USGS), 2009. Volcanic Ash: Effects and Mitigation Strategies. Available at: http://volcanoes.usgs.gov/ash/health/index.html.

U.S. Geological Survey (USGS), 2010. Volcanic Gases and Their Effects. Available at: http://volcanoes.usgs.gov/hazards/gas/.

Vaselli, O., Zassi, F., Tadesco, D., Barbara, N., Bruno, C., Yaliere, M., 2006. The lava lake-induced volcanic plume at Nyiragongo volcano (DRC): environmental effects on crop and population. Chin. J. Geochem. 25 (sup), 71–72.

Washington State Department of Health (WADOH), 2008. Public Health Emergency Preparedness and Response, Volcanoes. www.doh.wa.gov/phepr/handbook/volcano.htm.

Wilson, G., Wilson, T.M., Deligneb, N.I., Colea, J.W., 2014. Volcanic hazard impacts to critical infrastructure: a review. J. Volcanol. Geotherm. Res. 286, 148–182.

19

Wildfires

OBJECTIVES

- List the factors influencing the composition of wildfire smoke.
- Explain the effects of wildfire smoke on human health.
- Describe the toxic components of wildfire smoke.
- Explain how Air Quality Index measures help communicate smoke hazards.
- List populations at higher risk from wildfire smoke exposure.
- Explain how wildfire health risks can be mitigated.
- Recognize highly flammable and less-flammable plants.
- Describe the uses and limitations of air-purifying respirators during wildfires.
- Explain the challenges of sheltering wildfire evacuees.
- List the most effective public communication tools for wildfire response.

Introduction: 2011 Bastrop Complex Wildfire, Texas

The 2011 Texas summer was particularly harsh. July brought the hottest month logged since state recordkeeping began in 1895. That same month was also the third driest in state history. This unusually hot and dry pattern persisted for months, creating a statewide tinderbox. Burn bans and water restrictions were commonplace as reservoirs dropped below 50% and small streams and ponds disappeared. Many boat docks sat on cracked, dry mud. The agricultural industry chronicled tremendous losses due to limited water supplies and scorched terrain. Every day, over the course of several months, dozens of new wildfires sprang up across the state. The tireless efforts of firefighters limited much of the damage as thousands of acres burned every day, but the losses quickly mounted as fires became more widespread and difficult to control.

On September 1, relief appeared to be in sight. Tropical Storm Lee dropped heavy rain as it entered the Gulf of Mexico and slowly moved toward the Texas coast. Hurricanes pose a regular threat to Texas, and this impending storm would ordinarily be cause for alarm. Oddly enough, preparedness and response officials across the state were hoping for such a storm, just a little short of a hurricane, to move slowly across the state, dropping bountiful rain to break the drought and lessen fire risks. Unfortunately, Tropical Storm Lee turned north into Louisiana before reaching the Texas coast. Not only did Texas miss out on desperately needed rain, but instead the state received excessively high winds from the backside of the storm. The dry conditions, arid terrain, and high winds created ideal conditions for a severe, fast-moving fire.

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The picturesque town of Bastrop, Texas (USA), sits on the Colorado River about 20 miles east of Austin. Main Street is the embodiment of all that makes small town America warm and welcoming. It is a close-knit community with a strong sense of identity. The value of the town's social cohesion was about to be severely tested. The Texas drought destroyed several hundred million trees across the state in 2011 and weakened many more. As the winds picked up over that Labor Day weekend, many of those dead or dying trees twisted and cracked as they swayed in blustery winds. As wind gusts surpassed 30 miles per hour that day, the top of a dying tree plunged into nearby power lines, sparking a fast-moving fire. It merged with another small fire and quickly grew. The smoke and flames swept southward. As the fire advanced through the piney woods of Bastrop County, unsuspecting homeowners began to receive calls, texts, and knocks on their doors from friends, family, and local officials advising them to evacuate immediately. The growing wildfire threat was understood throughout the region, but the magnitude of this fire was difficult to comprehend (Fig. 19-1).

Jeannie Jessup was home with her husband and daughter when she received a call from a friend. A neighbor had smelled smoke and went outside to investigate. When she and her husband looked up the road, they saw the leading edge of the firestorm. Jeannie had been thinking about preparedness for some time. She met with a group of mothers in the months preceding the fire and discussed this type of threat. In fact, Jeannie said, "The day before, I had 'liked' the local EMA (Emergency Management Agency) on Facebook so I had their number and I called and asked them if this is real. They said, 'Yes, get out of there.' We had a fire nearby previously and we all had an idea of what to bring with us; scrapbooks, stuffed animals, etc." Her 3-year-old daughter sat calmly watching "Dora the Explorer" on

FIGURE 19-1 The massive Bastrop Complex Wildfire rapidly advances through Bastrop County, Texas on Sunday September 4, 2011. *Photograph by Kerri West.*

TV while Jeannie began piling belongings next to the front door. Her husband did not initially think the fire was too severe and drove down the road to get a closer look. The fire was about a quarter mile away and advancing fast. As they packed their vehicles, the sky above became black with smoke from the advancing fire. With only one road out of their rural neighborhood, they knew they needed to move fast. They hastily grabbed clothes, family photographs, and other essentials and mementos. As the flames raced toward their home, they pulled away in one small SUV and one hatchback carrying their two large dogs. They made their way onto the main road to town, joining a long, slow-moving line of traffic where they began their trip to stay with family and await news on their home.

A couple days had gone by when Jeannie received a call from a neighbor. Although reentry was restricted due to the hazardous conditions, their neighbors had gone back in early. They reported to Jeannie that her home was gone. Several days later, the Jessup family was allowed to reenter. What they saw was shocking. Jeannie shared photographs with friends and family who were asking for updates. It was unlike most house fires where there is some part of the house standing. She reported, "…this was different. It reduced everything down to ash about a foot thick" (Jessup, 2013).

The long road to recovery had begun for Jeannie and hundreds of families. The fire killed two people and destroyed 1673 homes. The losses were calculated at $325 million (ICT, 2011). The Bastrop wildfire burned over 34,000 acres and to date is the worst wildfire in Texas history (Gardner, 2014).

Wildfire Definitions

Air Quality Index (AQI) Measure of harmful substances present in the air that is used by US meteorologists and weather forecasters to report the purity of the air in a community on a specific day. A higher index indicates more pollution on a scale of 0–500. Once the AQI exceeds 100, it has exceeded national standards for key toxic substances. The higher it climbs, the greater is the public health impact.

Conduction Thermal energy (heat) transfer between two objects occurring from direct molecular contact. A means of heat transfer distinguished from convection and thermal radiation.

Convection Thermal energy (heat) flowing from one material to another through heated gases or fluids. A means of heat transfer distinguished from conduction and thermal radiation.

Firebrand Piece of burning wood or other material; an ember.

Fire mitigation Actions taken to reduce the impact of a wildfire on human health and property.

Fuel Both living and dead combustible materials that burn when provided heat and oxygen.

Home ignition zone (HIZ) A 100-ft (30-m) zone surrounding structures at risk for wildfires. The zone should be cleared of combustible vegetation and maintained in a manner that reduces the likelihood of a fire reaching the building.

Ladder fuels Vegetation providing fuel (such as shrubs and branches) that carries the fire from the ground to the tops of trees, the same way a person would climb a ladder.

N-95 respirator Air-purifying respirator that cleans 95% of the particles from the air before it is inhaled by the wearer.

Particulate matter Suspension of fine solids or droplets in the air such as dust, ash, smoke, and fumes.

Prescribed burns Forest management tool in which fire is carefully applied to forest fuels, for a specific purpose, under precise conditions, to achieve manageable objectives, such as to improve forage and habitat for wildlife or livestock, or to reduce hazardous build-up of fire fuels.

Thermal radiation Electromagnetic radiation produced by the thermal motion of charged particles of matter. Examples include sunlight or incandescent light bulbs emitting visible light, and infrared light. A means of heat transfer distinguished from conduction and convection.

Wildfire Rapidly spreading, unwanted fires that rage through forests or wildland areas threatening human lives, property, and natural resources.

Wildland Natural area without human development and habitation other than roads, power lines, and railroads.

Wildfires

Wildfires have always been part of nature's maintenance of the ecosystem and are often natural occurrences started by lightning strikes. They are also sometimes man-made through carelessness or malicious intent (arson). Wildfires pose the highest risk in areas with vegetation, winds, and periods of dry weather, including heavily wooded areas, grasslands, and regions with thick scrub or underbrush. Although these fires can naturally occur and actually have long-term benefits for some ecosystems, human habitation near susceptible areas can place populations at risk, putting them into the path of dangerous flames and unhealthy smoke and debris. The effects of wildfires on human populations include major public health, economic, and environmental damage.

There is also a recognized and sometimes controversial method of land management called "prescribed burns." There are many benefits and risks associated with these burns. Prescribed burns can improve some ecological systems and reduce future wildfire threats. However, if not managed and timed well, they may also pose serious risks to life and property. In addition to liability risks, these burns may promote soil erosion and worsen drought conditions by destroying the natural mulch covering the soil (Alexander and Thomas, 2006).

Prescribed Burning Benefits

While wildfires are unwanted fires in undesirable places, there are benefits to prescribed burning as a part of land management (Long, 2002). These benefits include:

1. Reducing accumulated vegetative density and the risk of future wildfires by establishing new growth which burns less intensely
2. Reducing competing vegetation in forest areas
3. Improving wildlife habitats by promoting new growth of nutrient-rich plants
4. Promoting germination and flourishing of native, fire-adapted plants
5. Enhancing quality of grazing lands
6. Increasing soil nutrient availability
7. Controlling pest problems
8. Killing pathogens
9. Improving access for tree planning and other beneficial changes
10. Enhancing the appearance of the area

Table 19-1 EPA Air Quality Index Summary (EPA, 2014)

AQI Value	Air Quality	Warning Colors
0–50	Good air quality; little or no risk	Green
51–100	Moderate; acceptable levels of pollutants will affect very few people	Yellow
101–150	General public not likely affected Unhealthy for sensitive groups including those with heart or lung disease, the elderly, children, and pregnant women	Orange
151–200	Unhealthy for everyone Potentially serious for sensitive groups	Red
201–300	Very unhealthy for everyone Everyone may experience some effect	Purple
301–500	Hazardous to everyone Entire population is affected	Maroon

The human impact of wildfires includes a range of health threats. Heat injuries and illnesses pose particular risks among those battling fires. The populations most vulnerable to heat, as well as the strategies for coping with the effects of heat, are described in Chapter 13, "Heat Waves." Risks of burn injuries are highest among first responders and untrained individuals electing to fight the fire rather than to evacuate. Protecting the public from heat and fire related injuries is the primary focus of first responders and is accomplished through rapid communication and evacuation. However, smoke is the most challenging and far-reaching public health aspect of wildfires.

Wildfire smoke is a complex assortment of gases and particles, including carbon dioxide, carbon monoxide, nitrogen oxides, water vapor, particulates, and thousands of other compounds. The specific composition of wildfire smoke depends on a variety of meteorological and environmental factors unique to every situation. Although there are differences in smoke composition from one wildfire to another, local air quality standards are useful in communicating health risks. The standards are used in major cities to inform the public of air pollution levels so decisions can be made concerning the risks of outdoor activities. The Air Quality Index (AQI) (Table 19-1) was developed by the US Environmental Protection Agency (EPA) based on measurements of five regulated pollutants (ground level ozone, particulate pollution, carbon monoxide, sulfur dioxide, and nitrogen dioxide) (EPA, 2000). The AQI takes the complex sum of risks associated with these primary pollutants and assigns a single number to communicate the level of public health risk. If the AQI is 100 or less, conditions are good for most people. The value of 100 corresponds to the US national standards for these pollutants. As the index climbs above 100, warnings are shared for vulnerable populations and at higher levels, the warnings apply to everyone.

For areas where AQI data exist, it is a good measure of public health risks associated with wildfire smoke. Similar AQIs are used in many other countries under other names including Air Pollution Index. The approach is the same, using standardized ambient air

pollution concentrations to produce an index equated to health risks, but the number of risk categories varies. Canada uses a 1-to-10 scale divided into four categories from "low" to "very high." The United States uses a 0-to-500 scale divided into six categories from "good" to "hazardous." These systems also use similar color coding from yellow to darker shades of red or purple. These scales share common limitations in using AQI measures to monitor public health risks during a wildfire. Most major wildfires occur in rural areas where AQI is not measured. In addition, AQI data are based on day-to-day urban pollution from traffic and industrial sources. If used as the absolute guidance for the public health response to wildfire smoke, the AQI can understate the level of risk (Table 19-2).

Table 19-2 Air Quality Index (AQI) International Comparisons (EC, 2013; PRC, 2012; CITEAIR, 2007; EPA, 2014)

Nation	Canada (1–10+)	Europe (0–100+)	China (0–300+)	United States (0–500)
AQI scale	Low (1–3)	Very low (0–25)	Excellent (0–50)	Good (0–50)
	Moderate (4–6)	Low (25–50)	Good (51–100)	Moderate (51–100)
	High (7–10)	Medium (50–75)	Lightly polluted (101–150)	Unhealthy for sensitive groups (101–150)
	Very high (>10)	High (75–100)	Moderately polluted (151–200)	Unhealthy (151–200)
		Very high (100+)	Heavily polluted (201–300)	Very unhealthy (301–400)
			Severely polluted (300+)	Hazardous (401–500)
Using similar scales	United Kingdom			India
				South Korea

Human Health Effects

Wildfires can cause a variety of injuries and illnesses. Beyond the obvious risk of burns and heat injuries, smoke is the most far-reaching and challenging wildfire public health concern. Wildfire smoke can produce effects ranging from airway and eye irritation to death, especially among individuals with conditions that make them more susceptible to inhalational exposures. This includes people with chronic lung disease, such as asthma or emphysema; children playing outdoors when their lungs may be more sensitive or not fully developed; elderly individuals with greater sensitivity; active adults rigorously exercising outdoors; and some who are genetically predisposed to ozone sensitivities (EPA, 2014; CDC, 1999). Although there are potentially thousands of chemicals in the smoke from any given wildfire, the primary short-term inhalational challenges are from particulate. Particles irritate the airway and cause symptoms even among healthy exposed individuals including coughing, wheezing, and difficulty breathing. Other smoke components have toxicity potential as allergens, carcinogens, mutagens, and teratogens. Some of these components are listed in Table 19-3. The majority of the exposed population will not experience

long-term effects from wildfire smoke. However, there are some vulnerable populations who may experience severe short-term effects and some may have chronic effects as well. Jayachandran (2009) described the impact of the 1997 wildfires in Indonesia leading to over 15,000 deaths in fetuses, infants, and children—a 1.2% increase in mortality. In an economic analysis of healthcare costs and wildfires, it is estimated that for 100 acres burned in an area of mixed population density between $60 and $210 in inpatient treatment costs is incurred for respiratory problems and $70 to $260 for cardiac problems (in US$ in US hospitals) (Moetler et al., 2013). The costs are dependent on distance from the fire and types of fuel. Kochi et al. (2012) observed heterogeneity in the health effects from the Hayman wildfires in California, USA. In San Bernadino, mortality was immediate and largely related to cardiac events, while in Anaheim the effects were delayed and were both cardiac and respiratory. The authors postulate the differences were related to age, income levels, background health risk, and access to services (Fig. 19-2).

FIGURE 19-2 Helicopters drop water and fire retardant on the 2007 Harris fire, near the Mexican border outside San Diego, California. *Photograph by Andrea Booher/FEMA.*

The 2008 North Carolina wildfires had a statistically significant relative risk for asthma related emergency department visits even after short-term exposure (Rappold et al., 2010). Research from the 2007 California wildfires suggests the particles in smoke produced by wildfires are potentially more dangerous than the smoke that normally exists in an urban setting from traffic and other sources. The fire emissions are able to penetrate into indoor environments more readily than vehicle emissions (Verma et al., 2009). Wildfire smoke particles also have greater bioavailability and are more easily absorbed by human tissue. These findings warrant further investigation and should be considered when making decisions on evacuation and sheltering (Table 19-3).

Table 19-3 Wood Smoke Toxic Component Examples (Naeher et al., 2007)

Smoke Component	Toxicity
Inorganic gases	
Carbon monoxide (CO)	Asphyxiant
Ozone (O_3)	Irritant
Nitrogen dioxide (NO_2)	Irritant
Aromatic hydrocarbons	
Benzene	Carcinogen/mutagen
Styrene	Carcinogen/mutagen
Oxygenated organics	
Aldehydes	Carcinogen/mutagen/irritant
Organic alcohols	Teratogen/irritant
Phenols	Carcinogen/mutagen/teratogen/irritant
Quinones	Oxidation reduction/irritant/allergen/possible carcinogen
Chlorinated organics	
Methylene chloride	Possible carcinogen/neurological depressant
Methylene chloride dioxin	Possible carcinogen
Free radicals	Oxidation reduction/inflammatory/possible carcinogen
Particulate matter	Irritant/allergen/inflammatory/oxidative stress

Prevention and Preparedness

Preparing for wildfires begins with an assessment of local risk and an understanding of local wildfire history. This information is available in most areas through the local emergency management office or by contacting a nearby fire department. Keep in mind a lack of history does not necessarily mean zero risk. A long dry weather period can introduce the risk of wildfires to areas with little or no history. Home preparedness recommendations include basic fire safety such as maintaining fire alarms on each floor and near every bedroom. Ingress and egress plans to homes are also essential.

Emergency managers and fire departments should promote wildfire preparedness activities throughout the community with specific focus on those living closer to areas at greater risk for wildfires. In addition, local preparedness planners should consider ingress and egress plans for first responders. A first responder ingress plan should consider how accessible a structure is to large fire trucks and how easily a home can be identified from the road. If the road is not wide enough or if the home cannot be identified from the road, it may hamper response and rescue efforts. This is particularly challenging in rural areas where roads and utilities are most vulnerable to wildfire disruption.

Understanding how fire spreads is helpful in assessing wildfire risks to homes and other structures. Conduction occurs from embers, also known as firebrands. Small pieces of burning materials can be propelled high into the smoke cloud by fire convection drafts. If the firebrands are still burning when they land on a combustible surface, they can pose an immediate threat even though the leading edge of the fire may be far away. Heat may also be transferred by convection through contact with flames and hot gases. Even if a combustible surface is not in direct contact with burning materials or flames, heat may also be transferred through thermal radiation or electromagnetic energy. Depending on the

Table 19-4 Highly Flammable Plant Examples

Trees	Shrubs	Groundcover and Other Plants
Bamboo	Acacia	Deer grass
Cedar	Arborvitae	Eulalia grass
Cypress	Gallberry	Pampas grass
Eucalyptus	Hopseed bush	Pine straw
Fir	Hollies	Rosemary
Pines	Junipers	Sage

size of a wildfire, how close it is to a structure, and how long the heat persists, a structural fire may start without direct contact with flames or burning materials. For this reason, it is important to create a home ignition zone (HIZ).

The concept of an HIZ was developed by Jack Cohen, a research scientist with the US Forest Service. Similar recommendations are promoted by a variety of governmental and professional organizations. Through many years of studying which structures are most likely to survive a fire and why, Cohen developed recommendations to reduce fire risks. He suggests starting with roof composition. If the roof is made of flammable material, such as thatch or non–pressure-treated wood, then the roof is susceptible to firebrands. To mitigate fire risks, builders should use treated fire-retardant wood or other nonflammable composite, metal, clay, or slate materials. In addition, gutters should be regularly cleaned to avoid accumulation of dry leaves or other combustible materials. A 100-ft (30-m) HIZ should be established around the house or other structure. This area should extend from the main structure and any attached structures such as a deck or garage. Within the HIZ, grass should be kept mowed and watered. Trees should be thinned out so there are no clusters of trees that could support high-intensity fires. Of particular concern are evergreen and broad leaf trees (Table 19-4). Branches should be trimmed up to 8 ft (2.5 m) high to reduce the possibility of the lower branches serving as ladder fuels to the upper section of the trees (FEMA, 2004). The types of vegetation in the HIZ should be carefully considered. Although all plants can burn, some are far less flammable than others, burn more slowly, have higher moisture content, and are generally safer to have close to a structure (see Table 19-5). In this safety zone, vines and shrubs should not be growing close to or in contact with the structure. Tree tops should be at least 15 ft apart to reduce the likelihood of fire spreading from one tree top to another. The lawn should be kept cut, watered, and free of accumulating leaves or branches. These measures will help suppress the advancement of fire close to a home or other structure.

Adherence to these precautions is a factor of personal risk perception. In a study performed by Kanclerz and DeChano (2013), in permanent and temporary residents of Teton County, Wyoming (USA), there were no differences in the perception of vulnerability and risk in those with local prior experience and those who were temporary residents. While residents recognized the benefits of recommendations to clear debris and to use fire protectant materials, they also suggested local officials perform informal assessments and specific recommendations to the homeowners in support of general guidelines. Additionally, the use of increased and improved communications, especially during high-risk seasons, with frequent reminders and door-to-door campaigns were identified by the participants. Financial incentives such as

Table 19-5 Less-Flammable Plant Examples

Trees	Shrubs	Groundcover and Other Plants
Ash	Azalea	Blue-eyed grass
Birch	Barberry	Daylily
Cherry	Camellia	Honeysuckle
Elm	Forsythia	Iris
Hickory	Gardenia	Lantana
Maple	Hydrangea	Periwinkle
Oak	Indian Hawthorne	St. Augustine grass
Plum	Oleander	Stonecrop
Redbud	Rose	Trumpet creeper
Magnolia	Spirea	Yarrow
Tulip	Viburnum	Yellow Jessamine
Willow	Weigela	Yellow-eyed grass

North American examples adapted from the East Coast, South Carolina Forestry Commission, and West Coast, Ventura County Fire Department (SCFC, 2005; VCFD, 2009).

insurance and homeowner's association costs may be beneficial. In high-risk communities, these outreach activities may prove useful to provide direct assistance and education.

Immediate Actions

The initial actions taken during a wildfire should be based on warnings of local officials, current and anticipated fire threats, and weather conditions. If there is a reasonable chance a wildfire will threaten human lives or property, evacuation orders are issued. For those outside the area of risk for fire hazards but close enough to experience smoke exposure, the AQI or its equivalent may be used, if available, to communicate the level of risk from smoke exposure (see Tables 19-1 and 19-2). The AQI provides a familiar and understandable set of instructions for the public. As previously mentioned, this approach may not be as protective as preferred since emerging research suggests the smoke from wildfires is potentially more toxic than typical urban smoke and smog, which is generally the basis of the AQI. However, the benefit of using the AQI is it fosters better understanding of how local air quality can threaten public health. In the United States, there are six categories that associate the AQI values, the quality of air or level of concern, and a corresponding color. These AQI categories of measurement and warnings vary across different nations and regions (Table 19-2).

Public information on wildfire preparedness and response should include basic information regarding evacuation and sheltering in place. Those trapped in stranded vehicles during a wildfire should stay in the vehicle and not attempt to outrun the advancing fire on foot. If the vehicle is operational, they should drive slowly with headlights on so others can see them through the smoke. Windows should be rolled up and air vents closed (Fig. 19-3). If the vehicle must be stopped during a wildfire, it should be parked as far away as possible from tall trees and heavy brush. If surrounded and trapped in a vehicle, occupants should stay inside the vehicle until the worst of the fires pass. Although the engine may stall and the car may rock from air currents generated by the fires, it is still safer to remain inside

FIGURE 19-3 The sun barely penetrates the smoke and ash as evacuees flee West Glenwood, Colorado, in 2002 because of the spreading wildfires. *Photograph by Bryan Dahlberg/FEMA.*

a vehicle. It is very unlikely the gas tank will explode, even when the temperature in the vehicle increases due to the passing fire.

When trapped inside a home or other structure, it is best to remain inside long enough for the worst of the wildfire to pass. The fire will likely pass before the remaining structure burns down and the building can provide a temporary shelter as the fire passes. If outside when the fire approaches, the best action is to find the closest area with the least amount of vegetation or fuel to burn. This area may be a road, ditch, or open field. If the threat of smoke is more of a danger than the actual fire, shelter-in-place actions can provide protection. For those downwind, air cleaners or purifiers can afford some relief by removing smoke particles from the air. Richardson et al. (2012) found people who experienced symptoms in the 2007 California wildfires and were more aware smoke could cause illness, were more likely to use air cleaners in the home. The authors estimated using this protective action represented a marginal value for one symptom-free day of $84.42 (USD). This figure reflects not only the actual cost of using the cleaner but also savings from the reduction of days absent from work, cost of necessary healthcare for symptoms related to the wildfire, etc.

Based on the current understanding of risks and benefits, neither evacuees nor professional firefighters should rely on respirators while outdoors during wildfires. Although many people purchase dust masks from local home supply stores to wear during wildfire smoke exposures, masks do not provide adequate protection. In fact, there are no air-purifying respirators, which offer suitable protection against heavy wildfire smoke. Every situation has unique respiratory protection needs and specific recommendations vary according to multiple scenario-specific variables. A properly fitted N-95 respirator offers some protection from smoke particles.

However, no air-purifying respirator is capable of filtering out carbon monoxide and several other hazardous wildfire smoke contaminants. Current recommendations for those residing downwind call for an air-purifying respirator and a carbon monoxide alarm (Austin and Goyer, 2007). Individuals relying on an air-purifying respirator for protection from wildfire smoke must be cautioned not all inhalational hazards can be filtered.

Response and Recovery

An initial public health and medical wildfire response includes assuring public notification, safe evacuation, and adequate sheltering for those at risk. Additionally, there is ongoing need throughout response and recovery for particular attention on responder safety and health. As seen in other acute, rapid-onset disasters, wildfire evacuees may not have even the most basic necessities. Shelters must be rapidly established and provide essential items such as toiletries. Provision for prescription medications must be considered in preparedness planning prior to a wildfire. Contingency contracts with pharmacy chains can facilitate meeting the immediate needs of those sheltered. Planning may assume certain pharmaceuticals will be most crucial during initial shelter operations. This includes oxygen tanks or concentrators, routine medications for diabetes and hypertension (Zane et al., 2012) and devices for insulin delivery and nebulizers (Jenkins et al., 2009). Durable medical equipment, such as bariatric supplies, is also essential and must be made available as needs are identified. Implementation of enhanced health surveillance for increased illnesses and injuries can supply data for targeted resources (Johnson et al., 2005).

During the 2011 Texas Bastrop Wildfire, the Texas Department of State Health Services deployed responder safety and health support for firefighters. A Mobile Medical Team (MMT) composed of four emergency medical technicians and logistical staff were deployed to the firefighter base camp established at Camp Swift, a nearby Texas Army National Guard base. Hundreds of elite firefighter teams from across the United States deployed to bring the immense wildfire under control. Day after day, these firefighters were carried by bus from Camp Swift to the leading edge of the fire. Although many firefighters were also experienced emergency medical technicians, their focus was directed intently on the fire and not on their own basic first aid. As they filed off buses at the end of their shifts, the MMT consistently observed a variety of unattended minor injuries. Over the course of about a week, the MMT treated over 100 injuries including sinus and respiratory infections, blisters, heat stress, and dehydration (Zane et al., 2012). The MMT also identified a growing need for basic sanitation support, including placement of hand sanitizer throughout the complex. The 2011 Bastrop Wildfire response experience highlights the need for public health and medical support in public shelters, as well as firefighter base camps.

Once a wildfire passes, residents should be restricted from returning to their property until immediate health and safety hazards are mitigated. Roofs of affected buildings must be inspected for fires and embers. Attics should also be inspected for sparks or fire hazards. If minor fire hazards are found, they should be neutralized by residents or local first responders. If local firefighters are not available, neighbors may assist in extinguishing fire

FIGURE 19-4 Fire fighters from ORE-CAL 1 work to secure the fire line on the 2003 Fishcreek fire Complex west of Missoula, Montana. *Photograph by Michael Rieger/FEMA.*

hazards. A garden hose may be used to control sparks and other minor hazards. If utilities are out, a garden hose may be connected to the outlet of a water heater. For several hours following a wildfire, there should be a "fire watch" with regular monitoring for signs of smoke and fire throughout nearby structures (Fig. 19-4).

Once the immediate risk of fire is controlled and the smoke begins to clear, the primary residual hazard is fire ash accumulation. Fire ash is very similar to fireplace ashes and not considered to be a significant hazard to most people. However, fire ash can pose a risk to susceptible groups including those with allergies or other sensitivities. Some exposed populations can experience skin and respiratory reactions. It is important to limit the exposure of children by cleaning play areas, toys, and pets. Sensitive individuals working on clean-up operations should cover exposed skin by wearing long sleeves, pants, and gloves. Airborne ash spread can be limited by using a high-efficiency particulate air (ie, HEPA) vacuum or wet cloth method for clean-up. Fitted N-95 respirators can also be used during clean-up (Fig. 19-5). Buildings or structures should be reentered carefully as risks from combustion of plastics or similar materials or and from partial combustion or incomplete burning of wood can exist. These products of combustion can accumulate from the high ambient temperatures alone even if the building does not appear to have been on fire.

The largest Arizona wildfire to date is the 2011 Wallow fire, which destroyed more than one-half million acres (>2000 km^2). A joint information system called the Northeast Arizona Public Information System was credited with protecting residents across the vast fire impacted area by providing timely, responsive information. The Apache County Public Health Services District (ACPHSD) used a variety of approaches to communicate with the public and various response organizations. Communication tactics included a volunteer-staffed call center, a separate call line for media inquiries, regular public meetings, and social media updates (ACPHSD, 2011). The effectiveness and consistency of these fire safety messages underscore the importance multiagency coordination, volunteer management, and use of multiple mediums for message delivery.

FIGURE 19-5 John Rossi, longtime friend of the Wagner family, spends his day helping sift through their belongings following the devastating 2007 California wildfire that destroyed their Rancho Bernardo, California, home. *Photograph by Andrea Booher/FEMA.*

Summary

Wildfires can threaten any area of human habitation near wildlands. The expansion of man-made structures into these areas will continue and a growing population will be at risk in the future. As these regions are developed, it is vital that mitigation and preparedness measures be incorporated into neighborhood and community planning. Mitigation measures include the selection of less-flammable landscaping plant varieties and construction materials. Safe zones must be established around buildings to reduce the fire risk to human occupants and property.

Even long-established urban, suburban, and rural communities should have enhanced wildfire preparedness planning. Although flames may not reach into some areas, smoke may impact the health of large downwind populations. Smoke is a particular risk for vulnerable

populations such as the very young, elderly, or those with existing respiratory or cardiovascular conditions. Community preparedness must focus on assisting these vulnerable populations in preparing in advance and in taking appropriate actions when fire threats are imminent.

Community awareness and education measures can reduce wildfire-associated morbidity and mortality by communicating basic mitigation steps to take to protect property and appropriate individual actions to take when a wildfire threat is looming. During a crisis, messages should be developed with multiagency input and shared through multiple media. If residents in high-risk areas follow the instructions of local officials during an incident and take the recommended actions, the risk of illness and injury from wildfires will be considerably reduced.

Websites

American Red Cross, Wildfire Preparedness. http://www.redcross.org/prepare/disaster/wildfire.

Centers for Disease Control and Prevention (CDC), Emergency Preparedness and Response, Wildfires. http://emergency.cdc.gov/disasters/wildfires/.

Federal Emergency Management Agency, Ready Campaign: Wildfires. http://www.ready.gov/wildfires.

National Institute of Environmental Health Sciences, Wildfire Documents and Resources. https://tools.niehs.nih.gov/wetp/index.cfm?id=2455.

Firewise Communities Program. http://www.firewise.org.

National Wildfire Coordinating Group. http://www.nwcg.gov.

U.S. Fire Administration, Wildfire Safety Outreach Materials. http://www.usfa.fema.gov/prevention/outreach/wildfire.html.

U.S. Forest Service, Climate Change Resource Center. http://www.fs.usda.gov/ccrc/topics/wildfire/.

U.S. Forest Service, Managing Wildfires. www.fs.fed.us/fire/management/index.html.

State of California, Department of Public Health. Wildfire Smoke: A Guide for Public Health Officials. www.arb.ca.gov/smp/progdev/pubeduc/wfgv8.pdf.

References

Alexander, M.E., Thomas, D.A., 2006. Prescribed fire case studies, decision aids, and planning guides. Fire Manag. Today 66 (1), 5–20.

Apache County Public Health Services District (ACPHSD), 2011. Multi-layered Communications Strategy Protects Residents in the Path of Arizona Wildfire. Available at: http://www.cidrap.umn.edu/practice/multi-layered-communications-strategy-protects-residents-path-arizona-wildfire.

Austin, C.C., Goyer, N., 2007. Respiratory protection for wildland firefighters: much ado about nothing or time to revisit accepted thinking. In: Wildfire 2007, International Wildland Fire Conference, Sevilla, Spain, May 13–18 Available at: http://www.fire.uni-freiburg.de/sevilla-2007/contributions/doc/SESIONES_TEMATICAS/ST6/Austin_Goyer_CANADA.pdf.

Centers for Disease Control and Prevention (CDC), 1999. Surveillance of morbidity during wildfires-Central Florida, 1998. MMWR 48 (4), 78–79.

Common Information to European Air (CITEAIR), 2007. Indices Definition. Available at: http://www.airqualitynow.eu/about_indices_definition.php.

Environment Canada, (EC), 2013. Air Quality Health Index Categories and Health Messages. Available at: http://www.ec.gc.ca/cas-aqhi/default.asp?lang=En&n=79A8041B-1.

Federal Emergency Management Agency (FEMA), 2004. At Home in the Woods: Lessons Learned in the Wildland/Urban Interface. Available at: http://www.fema.gov/pdf/library/woods/athome_woods.pdf.

Gardner, W., Wednesday, September 3, 2014. Bastrop County: Three years Later. Austin American-Statesman. Available at: http://www.statesman.com/news/news/local/bastrop-county-three-years-later/nhFFC/.

Insurance Council of Texas (ICT), 2011. Bastrop Wildfire Losses Rise, News Release. Available at: http://www.insurancecouncil.org/news/2011/Dec082011.pdf.

Jayachandran, S., 2009. Air quality and early-life mortality. J. Hum. Resour. 44, 916–954.

Jenkins, J.L., McCarthy, M., Kelen, G., Sauer, L.M., Kirsch, T., 2009. Changes needed in the care for sheltered persons: a multistate analysis from Hurricane Katrina. Am. J. Disaster Med. 4 (2), 101–106.

Jessup, J., July 2013. Personal Interview 26.

Johnson, J.M., Hicks, L., McClean, C., Ginsberg, M., 2005. Leveraging syndromic surveillance during the San Diego wildfires, 2003. MMWR 54 (Suppl. 1), 190.

Kanclerz, L., DeChano, L.M., 2013. Understanding wildfire vulnerability of residents in Teton County, Wyoming. Disaster Prev. Manag. Int. J. 22 (2), 104–118.

Kochi, I., Champ, P.A., Loomis, J.B., Donovan, G.H., 2012. Valuing mortality impacts of smoke exposure from major southern California wildfires. J. For. Econ. 18 (1), 61–75.

Long, A., 2002. Benefits of Prescribed Burning. FOR 70. School of Forest Resources and Conservation, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Available at: http://edis.ifas.ufl.edu/pdffiles/FR/FR06100.pdf.

Moetler, K., Kim, M.-K., Zhu, E., Yang, W., 2013. Wildfire smoke and health impacts: a closer look at fire attributes and their marginal effects,. J. Environ. Econ. Manag. 66 (3), 476–496.

Naeher, L., Brauer, M., Lipsett, M., Zelikoff, J.T., Simpson, C.D., Koenig, J.Q., Smith, K.R., 2007. Woodsmoke health effects: a review. Inhal. Toxicol. 19 (1), 67–106.

People's Republic of China (PRC) Ministry of Environmental Protection, 2012. Technical Regulation on Ambient Air Quality Index (Chinese). Available at: http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/201203/W020120410332725219541.pdf.

Rappold, A.G., Stone, S.L., Kilaru, V., Peters, A., Barnett, C., Deyneka, L., Vaughan-Batten, H., Ising, A., Szykman, J., Cleve, W., Meridith, J., Carraway, M., Cascio, W., Devlin, R., 2010. Asthma and respiratory related emergency room visits associated with a wildfire in eastern North Carolina in the summer of 2008. Am. J. Respir. Crit. Care Med. 181, A2423.

Richardson, L.A., Champ, P.A., Loomis, J.B., 2012. The hidden cost of wildfires: economic valuation of health effects of wildfire exposure in southern California. J. For. Econ. 18 (1), 14–35.

South Carolina Forestry Commission (SCFC), 2005. "Fire Smart" Plant List for SC Native and Landscape. Available at: http://www.state.sc.us/forest/scplants.pdf.

U.S. Environmental Protection Agency (EPA), 2000. Air Quality Index: A Guide to Air -quality and Your Health. Environmental Protection Agency, Research Triangle Park, NC. Publication: EPA-454/R-00-005.

U.S. Environmental Protection Agency (EPA), 2014. Air Quality Index (AQI) – A Guide to Air Quality and Your Health. Publication EPA-456/F-14-002. Available at: http://www.epa.gov/airnow/aqi_brochure_02_14.pdf.

Venture County Fire Department (VCFD), 2009. Flammable Plant Guide. Available at: http://fire.countyofventura.org/PublicInformation/WildfirePreparedness/FlammablePlantGuide/tabid/170/Default.aspx.

Verma, V., Polidori, A., Schauer, J.J., Shafer, M.M., Cassee, F.R., Sioutas, C., 2009. Physicochemical and toxicological profile of particulate matter (PM) in Los Angeles during the October 2007 southern California wildfires. Environ. Sci. Technol. 43 (3), 954–960.

Zane, D.F., Jones, R., Huss, J., Sanches, K., Hoogheem, J., Clements, B., 2012. Public health emergency response to a massive wildfire in Texas (2011). Tex. Public Health J. 64 (4), 6–8.

20

Winter Storms

OBJECTIVES

- Recognize the types of winter storm warnings and watches.
- List the elements needed to cause a winter storm.
- Describe the primary and secondary hazards created by winter storms.
- Define the four mechanisms responsible for heat depletion from the body.
- List the physical risk factors for cold injury.
- Recognize the severity levels of frostbite injury.
- Describe freezing and nonfreezing cold injuries.
- Explain how to prepare a home and a vehicle for severe winter weather.
- List the actions to take when stranded in a vehicle during a winter storm.
- Describe the secondary causes of winter weather morbidity and mortality.

Introduction: 2007 US Midwest Ice Storms

An interesting phenomenon occurs in the aftermath of most disasters. It may be human nature to move forward and forget, but some catastrophes stay with those who experience them first hand. With massive hurricanes, earthquakes, volcanoes, and other violent displays of nature, it seems expected that people will remember and discuss them for years to come. An ice storm seems far less memorable. However, the 2007 Midwest ice storm was one event that remains on the minds of those who experienced it.

In January 2007, a series of winter storms swept across Oklahoma and Missouri. The storms started on Friday the 12th and continued throughout the weekend. The Midwest area is famous for tornadoes and other weather phenomena resulting from the convergence of weather systems, and this system was no exception. A warm, saturated cloud rose above a layer of cold air. As the rain fell through freezing temperatures below, the droplets became "supercooled." In other words, the droplets remained in a liquid state but were below freezing temperatures on impact and quickly turned to ice. This encased everything with ice; including streets, power and utility lines, and trees.

As ice accumulated, power lines began to break. Many were knocked down by falling branches as trees buckled and split under the tremendous weight of the ice. In Springfield, Missouri, alone, more than 300 utility poles had to be replaced, leaving about 75,000 residents without power for up to 2 weeks during freezing temperatures. National Weather Service meteorologist John Gagen called the storm a "50-year event" and said the accumulated weight of the ice on local utility poles and lines was more than 2 tons per pole, equivalent to the weight of a Chevy Suburban added to every utility pole in town (Johnson, 2008).

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Although a significant ice storm is expected in the area about every 20 years, this storm was considered as an exceptional event occurring once every 50 years (Fig. 20-1).

The ice coating on the streets made it difficult to hold a vehicle on the road for those who ventured out. Although few people wanted to get out on the roads, it was necessary for those who were not prepared. Trips to pick up essential items were difficult, and few open stores could be found. As with most disasters, it was particularly difficult for vulnerable populations and those with preexisting health conditions. Individuals in rural areas who depend on home health visits were isolated. Some in critical need of dialysis, medical equipment, medications, or other essentials experienced potentially life-threatening delays. Shelters were established to care for many individuals with functional and medical needs. Fortunately, no fatalities were attributed to the interruption in medical services and support, but it was certainly considered a wake-up call for the individuals and the communities affected.

In Oklahoma, the ice storms cut off power to over 100,000 homes and were responsible for nearly 3000 trips to local hospitals. At least 32 deaths were attributed to the storms, including 19 motor vehicle accidents, eight cases of hypothermia, two cases of smoke inhalation, and three falls (OEM, 2007). The situation was similar in Missouri, where thousands were without power and at least 15 people died from storm-related conditions. Like Oklahoma, many were due to traffic fatalities. Seven died in traffic accidents and an equal number in Missouri died from carbon monoxide poisoning from using gasoline-powered deices in closed spaces (SEMA, 2007). There was also the tragic case of 68-year-old Mary Maud East of Clinton, Missouri, who died from injuries she suffered when her barn collapsed under a heavy accumulation of ice and snow.

FIGURE 20-1 The US National Weather Service office in Springfield, Missouri, surrounded by damaged or fallen ice-covered trees due to the January 2007 winter storm. *Photograph courtesy of the US National Weather Service, Springfield, MO.*

Winter storms can be deceptive. Although this scenario of an ice layer across two states does not appear as dramatic as many other natural disasters, it is just as deadly. The evidence of the storm was apparent for a season, but once the missing branches and downed trees have been cleared and the utilities repaired, the trees grow back and memory of the storm and its intensity fades. Residents in hard-hit areas still talk about the storm but less frequently than in the past. It is unclear if this waning interest is because of their confidence in preparedness measures taken since the storms or if it is the onset of apathy.

Winter Storm Definitions

Blizzard warning Sustained winds or gusts of 35 miles per hour (56 km/h) or greater with significant falling or blowing snow limiting visibility to less than a quarter mile (400 m); expected to continue for 3 or more hours.

Blizzard watch Sustained winds or gusts of 35 miles per hour (56 km/h) or more with significant falling or blowing snow limiting visibility to less than a quarter mile (400 m); expected to continue for 3 or more hours is possible within the next 36 h.

Blowing snow advisory Widespread blowing of snow; winds 25–35 mph (40–56 km/h), with occasional visibility restrictions to less than one-quarter mile (400 m).

Chilblains (also known as pernio and perniosis) Inflammation of the skin with painful, itchy patches caused by an abnormal reaction to cold temperatures.

Conduction Transfer of heat through a substance due to a heat difference between the two (eg, loss of body heat from sleeping on cold ground).

Convection Transfer of heat in a gas or liquid (eg, loss of body heat from high winds).

Evaporation Transfer of heat when liquid is converted into a vapor (eg, loss of body heat from conversion of moisture on the body to vapor).

Freezing rain Rain that freezes when it hits the ground; may coat roads, walkways, trees, and power lines with ice.

Freezing rain advisory (also "freezing drizzle") Freezing rain is expected to accumulate from trace amounts up to ¼ in. (1–6 mm).

Frostbite Damage to skin and underlying tissue from freezing. Ice crystals form inside the cells causing the cells to rupture and die.

Frostnip Freezing of the top layers of skin; usually seen on fingers, toes, cheeks, and earlobes. Frostnip is reversible if treated by slow warming. If not treated, it can progress to frostbite.

Frost/freeze warning Widespread frost during growing season; temperatures at or below 32°F (0°C) expected. A "hard freeze" has temperatures below 28°F (–3°C).

Heavy snow warning Heavy snowfall amounts are imminent. The definition of "heavy" varies by region.

Hypothermia Abnormally low body temperature.

Ice storm warning ("freezing rain warning" in Canada) Heavy ice accumulation is occurring or imminent. The definition of "heavy" varies by region but usually ranges from ¼ to ½ in. (6–12 mm) or more of freezing rain.

Lake effect snow warning Heavy snow with amounts of 6 in. (15 cm) or more in 12 h or less or 8 in. (20 cm) in 24 h or less is occurring or imminent. It is the result of a cold air mass crossing over warm water. The lower layer of air is warmed and picks up water vapor from the lake

Radiation The transfer of heat due to surrounding objects having lower surface temperatures than the body. It is not due to air motion (convection) or surface contact (conduction).

Sleet Rain turning to ice before reaching the ground; may also cause moisture on roads to freeze and become slippery.

Sleet warning Sleet accumulations of 2 in. (5 cm) or more are occurring or imminent in the next 12 h.

Snow advisory Moderate snowfall amounts are occurring or imminent. The definition of "moderate" varies by region.

Trenchfoot Nonfreezing cold weather injury resembling frostbite. Trenchfoot is caused by prolonged exposure to cold, wet conditions and was a particular problem for soldiers involved in trench warfare during World War I.

Wind chill Apparent temperature that describes the combination of low temperatures and the effect of wind on exposed skin.

Wind chill warning Extreme wind chill temperatures are occurring or imminent. The temperatures vary by region.

Winter storm warning Winter storm is imminent or occurring. Hazardous conditions may include snow, freezing rain/sleet, and strong winds.

Winter storm watch Winter storm is possible within the next 36 h. Hazardous conditions may include snow, freezing rain/sleet, and strong winds.

Winter weather advisory Hazardous winter conditions are likely or imminent; the term is used for a combination of two or more conditions including snow, freezing rain/drizzle, sleet, and blowing snow.

Winter Storms

No other potential natural disaster threat has been romanticized and celebrated like winter weather. As songs like "White Christmas" and "Winter Wonderland" fill the airwaves, it is easy to see why many people are lulled into forgetting the risks associated with winter storms. These storms include a variety of hazards including low temperatures, high winds, freezing rain, sleet, and heavy or blowing snow. Winter storms form in a variety of ways but their formation has three common components including cold air, moisture, and lift. Obviously for snow and ice to form, the temperature must be below freezing. In addition, moisture must be present and lifted into the atmosphere to form clouds and precipitation. This usually occurs when a mass of warm air collides with cold air and is forced above it. It can also occur from air flowing up a mountain side or off a lake.

Extreme cold is regionally defined. Though it may be normal for Fairbanks, Alaska, to sustain cold that freezes a river solid enough for local residents to drive cars on it, it is also considered extreme cold in Orlando, Florida, if the weather reaches freezing temperatures on one night and damages citrus crops. Although the perceptions and definitions change by region, the one common factor is vulnerable populations. The very young and old are affected most by low temperatures regardless of local norms and extremes. Regional infrastructures are established around these temperature norms. Though some regions can sustain weeks or months of extremely low temperatures with no apparent impact on local utilities and essential services, other regions begin to experience pipes bursting with a single night of low temperatures because homes are not as well insulated or heated.

High winds are also common with winter storms. If winds accompany snow, it can result in reduced visibility, deep snow drifts, and hazardous wind chill factors. During ice storms, winds can knock down ice laden trees and power lines. Near coastal areas winds can cause flooding and property damage, endangering the lives of local residents (Fig. 20-2). In mountainous areas, winds can descend the side of a mountain causing gusts of over 100 miles per hour.

FIGURE 20-2 A blizzard in the Evergreen area with near white-out conditions, Colorado, March 2003. *Photograph courtesy of the National Oceanic and Atmospheric Administration.*

Heavy ice or snow accumulation can lead to fatal motor vehicle accidents. Large areas can be paralyzed by disrupted utilities, including power and communication. This can isolate vulnerable individuals from critical services. Even a small accumulation of ice can cause dangerous conditions for motorists and pedestrians. These deceptively dangerous ice accumulations will typically result in a patient surge of slip and fall injuries at local emergency departments. Larger accumulations of ice or snow can collapse buildings and cut off local residents from home, healthcare, fire, police, ambulance, and other vital services. Livestock can be lost as they are cut off from food and water. Avalanches can result from heavy snow in mountainous regions.

The cost associated with winter storms is often extremely high. The cost of snow removal efforts alone can be staggering. By late January 2005, Massachusetts had exhausted their $37.6 million budget for snow removal from the state's highways and government properties. The Governor requested an additional $28 million when over 42 in. (106 cm) of snow fell in a single month, breaking a 113-year-old record for Massachusetts snowfall in a single month (Johnson and Levenson, 2005).

Human Health Effects

Although humans have the ability to acclimate to a variety of environments, extreme cold is an exception. The environment can quickly draw heat from the body leading to localized or systemic injuries. As the body produces metabolic heat, it moves from the muscle

tissue to the skin. The ambient air temperature, wind speed, moisture, sunlight, clothing, and other factors influence how much heat is retained by the body and how much is lost to the environment.

The loss of body heat to the environment takes place through four mechanisms: convection, conduction, evaporation, and radiation. Convection is the transmission of heat from the body to the surrounding air or water. This includes the loss of body heat due to high winds. Conduction is the loss of heat from contact between two surfaces. For example, heat passes from an individual's feet to the ground if they have poorly insulated shoes. Evaporation is the loss of heat from water turning to vapor. This includes the loss of body heat from sweating and respiration. Finally, radiation heat loss is when surrounding surfaces have lower temperatures and the body experiences a loss of heat that is not from direct contact or wind (USA, 2005). These processes work together to draw heat from the body and can result in three possible cold injury scenarios: localized injuries, systemic injuries, or a combination of both.

Risk Factors for Cold Injury

Physical Factors

- Elderly (age > 65 years)
- Infants (age < 1 year)
- Physically disabled
- Mentally impaired
- Concurrent infectious disease
- Fatigue
- Smoking
- Malnourished
- Engaged in winter sports, outdoor exercise, or work
- Users of alcohol or illegal drugs
- Medical conditions that affect the body's ability to produce heat or with decreased sensation such as spinal cord injury, diabetes, stroke, hypothyroidism, Parkinson's disease, and arthritis

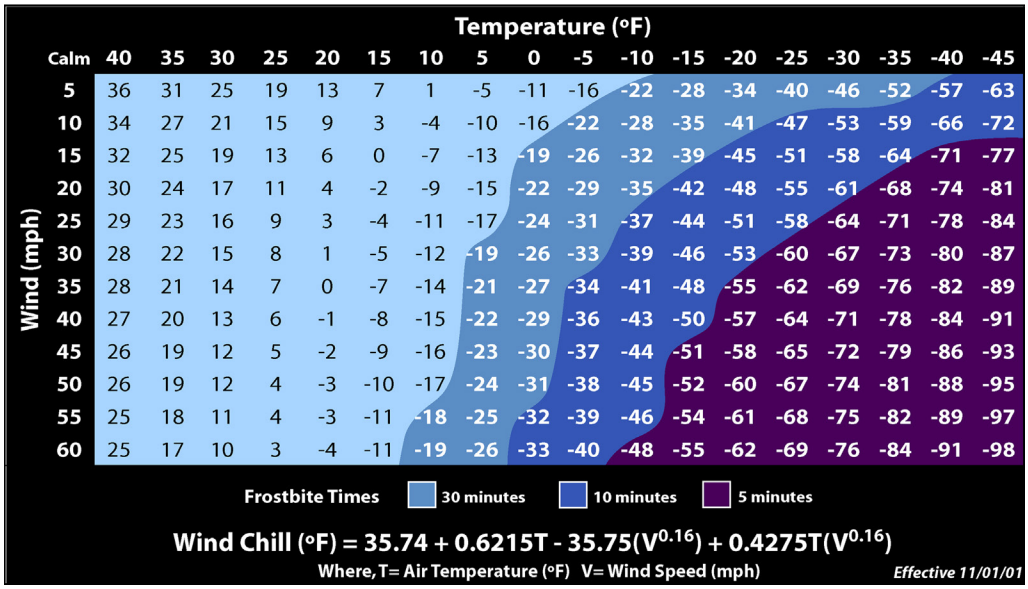
Social Factors

- Low income
- Homelessness
- Social isolation
- Urban residence
- Poor access to healthcare or warming shelters

Weather Factors

- Low ambient temperatures
- Strong winds
- Wet conditions

Table 20-1 Wind Chill Chart (Fahrenheit), US National Weather Service



Localized cold injuries range in severity from frostnip to frostbite. Frostnip is a minor peripheral injury occurring when the top layers of skin begin to freeze. It is typically seen on fingers, toes, cheeks, and earlobes. Although it is a minor injury where tissue remains pliable and blood circulation continues to the affected area, it can still be painful and can progress to frostbite if the exposed area is not warmed. Frostbite occurs as blood flow to the affected area is restricted or stopped. The variables which determine the severity of the injury are temperature, length of exposure, wind speed, and moisture. Skin can be exposed to temperatures below 32°F (0°C) for several hours without injury if there is little moisture and winds are low. However, if the wind speed increases or if moisture is present and evaporating, it can diffuse the layer of warm air normally surrounding the body and lead to localized cold injuries (Tables 20-1 and 20-2). If frostbite is not treated quickly, the damage will be permanent. The lack of oxygen from poor blood circulation leads to tissue and nerve damage. The damaged skin becomes discolored turning red, then progressing to bluish, then purple and eventually to black, similar to a bruise. This process is more difficult to observe in darker-skinned people. The severity of the injuries is determined by the area of injury, the length of time the skin remains frozen, and the particular risk factors of the individual exposed. Health conditions such as diabetes or habits like smoking or alcohol use restrict blood

Table 20-2 Wind Chill Chart (Celsius), Canadian Center for Occupational Health and Safety

WIND CHILL CHART

		Ambient Temperature (°C)								
		4	-1	-7	-12	-18	-23	-29	-34	-40
Wind km/h	Velocity mph	Equivalent Chill Temperature (°C)								
Calm										
0	0	4	-1	-7	-12	-18	-23	-29	-34	-40
8	5	3	-3	-9	-14	-21	-26	-32	-38	-44
16	10	-2	-9	-16	-23	-30	-35	-43	-50	-57
24	15	-6	-13	-20	-28	-36	-43	-50	-58	-65
32	20	-8	-16	-23	-32	-39	-47	-55	-63	-71
40	25	-9	-18	-26	-34	-42	-51	-59	-67	-76
48	30	-16	-19	-22	-36	-44	-53	-62	-70	-78
56	35	-11	-20	-29	-37	-46	-55	-63	-72	-81
64	40	-12	-21	-29	-38	-47	-56	-65	-73	-82

Adapted from: Threshold Limit Values (TLV™) and Biological Exposure Indeces (BEI™) booklet; published by ACGIH, Cincinnati, Ohio

Little danger *in less than one hour exposure of dry skin*

DANGER- *Exposed flesh freezes within one minute*

GREAT DANGER- *Flesh may freeze within 30 seconds*

Maximum danger *of false sense of security*

flow and make some exposed populations more susceptible to serious localized cold injuries than others.

Frostbite Severity

First degree: Epidermal or surface involvement; causes some redness, swelling, and sensitivity for a few weeks.
Second degree: Full thickness of the skin freezes; swelling and blisters for weeks progressing to dark eschars.
Third degree: Freezing goes deeper than the skin; hemorrhagic blisters form, bluish-gray skin, painful rewarming; gangrenous eschars.
Fourth degree: Muscle, bone, and tendons involved.
Adapted from Reamy (1998).

Other localized injuries result from a combination of cold temperatures and moisture. These nonfreezing cold injuries include chilblains and trenchfoot. Chilblains, or pernio, are painful, itchy patches of inflamed skin. They are caused by an abnormal reaction to cold temperatures (Simon et al., 2005). These injuries can also occur if cold skin is warmed too quickly. Trenchfoot is a more serious nonfreezing injury that was a particular problem during World War I among troops fighting in the trenches. Their mission required them to spend long hours standing in cold water leading to a condition resembling frostbite.

Your feet swell to two or three times their normal size and go completely dead. You could stick a bayonet into them and not feel a thing. If you are fortunate enough not to lose your feet and the swelling begins to go down. It is then that the intolerable, indescribable agony begins. I have heard men cry and even scream with the pain and many had to have their feet and legs amputated.

World War I Veteran Sergeant Harry Roberts (Kelly and Whittock, 1995).

The most important direct cause of winter weather morbidity and mortality is hypothermia or low body temperature. This is a systemic cold injury that can quickly become life threatening. Hypothermia is considered mild when the core body temperature is greater than 90°F (32°C) and less than 95°F (35°C), moderate when the temperature is from 82°F (28°C) to 90°F (32°C), and severe when the body temperature is less than 82°F (28°C) (Danzl and Pozos, 1994). One of the initial signs of hypothermia is the impairment of mental function. It is often compared to a person appearing "drunk" with slurred speech, tiredness, and disorientation. As body temperature drops, it will eventually lose the ability to shiver. Shivering is a protective reflex and is lost with moderate hypothermia. Eventually, the hypothermia victim can no longer move at all. However, some victims appearing to be dead with low body temperatures, dilated pupils, and no detectable breathing or pulse, have been revived through CPR and slow warming of the body. This is most frequently observed with individuals who are experiencing hypothermia from exposure to cold water versus ambient temperatures. According to the US Search and Rescue Task Force, cold water reduces body temperature 32 times faster than cold air (Tables 20-2 and 20-3).

The majority of winter weather morbidity and mortality is the result of secondary causes such as motor vehicle accidents, heart attacks from exertion, musculoskeletal injuries, slips and falls, and carbon monoxide poisoning. The leading cause of winter storm deaths is motor vehicle accidents which account for about 70% of winter storm deaths. Heart attacks are also common as people who rarely exercise overexert themselves shoveling snow. The inhalation of cold air can induce or worsen bronchoconstriction and exacerbate or initiate acute episodes related to asthma. Increased exercise such as shoveling snow and walking in deep snowfall increases the workload of the heart. Those with chronic respiratory or cardiac conditions can experience deterioration in their health status. Slip and fall injuries can result in traumatic head injuries or fractures. Carbon monoxide (CO) is a colorless, odorless gas found in exhaust from vehicles, stoves, generators, and other sources of combustion. As people turn to alternative sources of heat when there are power outages during winter storms, they sometimes use equipment such as generators without properly venting exhaust, which can lead to CO poisoning. Micropopulations with unique cultural practices may be more at risk for CO poisonings. For example, newly immigrated families with limited means and social connections may rely on practices from their native countries where indoor air exchange was different and less likely to have extreme noxious gas accumulation. Houck and Hanson reported 91% of CO poisonings in Washington state during winter storms occurred in ethnic minorities. CO poisoning also occurs as people stranded on roads continue to

Table 20-3 Time to Unconsciousness and Death in Cold Water

Water Temperature	Time to Exhaustion or Unconsciousness	Time to Death
<32°F (<0°C) Visible ice in freshwater Anchorage, AK, coast in winter	<15 min	<15–45 min
32–40°F (0–4.5°C) Boston Harbor in winter Great Lakes in winter	15–30 min	30–90 min
41–50°F (5–10°C) North Pacific coast in winter North Atlantic coast in spring	30–60 min	1–3 h
51–60°F (10.5–15.6°C) Southern California coast in winter Carolina coasts in winter	1–2 h	1–6 h
61–70°F (16.1–21.1°C) Southern California coast in summer Great Lakes in summer	2–7 h	2–40 h
71–80°F (21.7–26.7°C) Hawaiian coast in summer Puerto Rican coast in winter	3–12 h	Indefinite
>80°F (>27°C) Gulf of Mexico in summer South Atlantic coast (GA/FL) in summer	Indefinite	Indefinite

Adapted from United States Search and Rescue Task Force, Cold Water Survival Guide. Available at: http://www.ussartf.org/cold_water_survival.htm.

run their vehicles for warmth without clearing the area around the exhaust pipe, causing exhaust to back up inside the vehicle. These secondary winter storm deaths are preventable through basic awareness for the populations at risk.

Prevention

The preventive steps necessary to reduce winter storm morbidity and mortality begin with and build upon the basic preparedness measures described in Chapter 2, Public Health Preparedness Capabilities. Preparedness kits for homes should focus on things needed if heat, power, or other utilities are lost for several days. Residents of rural and suburban areas should be encouraged to be prepared for weeks of isolation and disruption of services. While some rural communities may be more resilient, specific populations such as the elderly and newly relocated urbanites may be more at risk. Many suburban households rely on "just-in-time" purchasing and supply lines may get disrupted for prolonged periods of time. In addition to the inability to move outside of the home, loss of power and school closures could result in "cabin fever": increased feelings of isolation, boredom, and seasonal affective disorder. People with underlying mental and behavioral health conditions should discuss with their providers helpful tools for surviving winter storm effects. When

winter weather is anticipated, there should be an adequate supply of prescription medication kept on hand. For those who have medical conditions requiring home care, dialysis, or other vital services, a discussion should occur with providers on what should be done if winter weather results in service disruption. Patients with power-dependent medical devices should have plans for continuity of care with their medical device supplier. Many power companies offer registration for homes that have medical power needs and can target responses to these individuals for early restitution of service. Home preparedness kits should focus on items needed to keep warm, fed, hydrated, and safe and a similar kit should be placed in each vehicle. The supplies in each vehicle should be established with a worst case scenario in mind (Fig. 20-3). Those residing in rural areas with potential to be isolated for an extended period of time should have more preparedness supplies in their vehicle than those who seldom drive outside densely populated urban and suburban areas.

FIGURE 20-3 US Red Cross workers search for victims buried in cars following snowfall during the Blizzard of "77." *Photograph courtesy of the US National Weather Service.*

Public Information and Warnings; Winter Weather Home Preparedness Messages

As the threat of severe winter weather rises, public messaging should focus on vulnerable populations and include the following:

- Homes should be winterized to retain heat by insulating walls and attics, caulking and weather-stripping doors and windows, and installing storm windows or covering windows with plastic.

- Charcoal or gas grills and generators should never be used indoors.
- Lit candles should never be unattended.
- Barns, sheds, or other structures that provide shelter for family, neighbors, livestock, or equipment should also be winterized.
- Rain gutters should be cleaned, roof leaks repaired, and tree branches cut away.
- Pipes should be insulated or faucets allowed to drip during cold weather to avoid freezing.
- Fire extinguishers should be kept on hand, and all residents should know how to use them.
- Locations of water shut-out valves should be known in the event of a burst water pipe.
- Elderly or disabled friends or neighbors should be identified in advance and checked on periodically.

  Instructions on establishing a winter storm supply kit:
- First-aid supplies and essential prescription medications.
- Battery-powered portable radio to receive emergency information, flashlights, and extra batteries.
- Food supply (dried fruit, canned food with a can opener, or other food which do not require heat or cooking).
- Bottled water (at least 1 gallon per person per day for at least 3 days).
- Warm clothing, including hat, gloves, and boots.
- Extra blankets.
- Essential baby items if there is a child in the home.
- Necessary pet food and supplies for at least 3 days.
- Emergency heating source, such as a fireplace, wood stove, space heater, etc.
- Fire extinguisher and smoke detector. (Test units regularly to ensure they are working).

  Instructions on Winter Weather Vehicle Preparedness
- Winterize vehicles before the winter season begins. This includes checking or having a mechanic check:
  - Antifreeze levels: sufficient to avoid freezing.
  - Battery and ignition system: in top condition with clean battery terminals.
  - Brakes: check for wear and fluid levels.
  - Exhaust system: check for leaks and crimped pipes.
  - Fuel and air filters: replace and keep water out of fuel lines using additives.
  - Heater and defroster: proper function.
  - Lights and flashing hazard lights: proper function.
  - Oil: check for level and weight. Lighter oils are better at lower temperatures.
  - Thermostat: proper function.
  - Windshield wipers and washer fluid level checked.
  - Tires checked: Ensure tires have adequate tread. All-weather radials are usually adequate for most winter conditions. However, some jurisdictions require vehicles be equipped with chains or snow tires with studs.
- Fully charge and carry a cell phone.

- Keep gas tanks near full to avoid ice in the fuel lines and to avoid running out of gas if stranded.
- Avoid traveling alone, especially in rural areas.
- Let others know travel timetables and routes.
- Carry a winter storm supply kit that includes:
  - An extra change of warm clothing
  - Blankets/sleeping bags
  - Flashlight with extra batteries
  - Windshield scraper, brush, and shovel
  - A bag of sand or cat litter to pour under tires for traction if they are stuck
  - A brightly colored, preferably red, piece of cloth to tie to a car antenna or side mirror to let others know there is someone in the car under duress
  - Tow rope or cable, small tool kit, and booster cables
  - A small supply of extra water and nonperishable food
  - First-aid kit

  Adapted from multiple sources including the American Red Cross, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, and National Highway Traffic Safety Administration.

Public information must reinforce basic messages of wearing appropriate clothing offering the best protection during a winter storm. This includes wearing layers of loose clothing. If sweating begins, layers can be removed to stop perspiration to avoid a subsequent chill. The trapped air in loosely fitting clothes provides insulation. A major key to reducing the risk of cold injuries is staying dry and that includes reducing the accumulation of moisture produced by the body. "Cotton kills, nylon thrills" is a popular saying among hikers and outdoorsmen. Wet cotton clothing does not wick moisture away from the body. Instead, the cotton clothing holds moisture against the skin and draws body heat through conduction. Cotton also becomes heavy and abrasive when it gets wet. Clothing should be also worn loosely and in layers so tight clothing does not restrict blood flow to the extremities or restrict movement. Tightly woven, waterproof fabrics can be worn on the outside to keep external moisture from getting close to the skin. Protecting the extremities is essential. Waterproof, insulated boots should be worn to keep the feet warm and dry. Gloves should be worn to protect the hands and fingers. Mittens that fit well around the wrists are better at keeping the hands warm than gloves. A hat should be worn and the ears and face should be covered. If temperatures are extremely cold, warnings should also be shared about the risks of touching metal objects with bare skin. The small amount of moisture on the skin can immediately freeze to cold metal surfaces and result in serious injury.

Individual health measures are also essential to reduce risks of cold injuries, especially for those working outside. The body should be well nourished and well hydrated. The use of alcohol, tobacco and drugs increases susceptibility and should be discouraged. Those who are fatigued or ill should also avoid cold exposure.

Immediate Actions

When threatening winter weather approaches, it is important to keep the public informed using as many modes of media as possible including radio, television, text messages, and social media. Populations at risk should be encouraged to take the basic health measures previously mentioned, to eat and hydrate well and avoid excessive use of alcohol or caffeine. Those at risk include individuals with chronic respiratory or cardiovascular disease and those taking medications which weaken the body's thermoregulatory function. In addition, those who are very young, very old, poor, homeless, alcoholic or drug addicted are at greater risk (Berko et al., 2014). Public messages should be reinforced addressing three scenarios: what to do if caught outside, stranded in a vehicle, or isolated at home without power or other vital utilities and services.

Public Messaging for Those Caught Outside

"If you are caught outside during a winter storm the priority is staying dry and warm, so seeking shelter is essential. If shelter cannot be found, limit exposure to the wind by preparing a makeshift shelter with anything available, even if that means using snow accumulation to block the wind. If possible, build a fire for warmth and to draw attention to your location."

Public Messaging for Those in Vehicles

"If you must travel in your vehicle during winter weather, try to drive only during the day, on main roads, and avoid traveling alone. Be especially cautious on overpasses and bridges as they are often the first to freeze in winter weather. If you are stranded in a vehicle, your best chance of survival is to stay in your vehicle. You should pull off the road when it is safe and turn on the vehicle's hazard lights. You also may want to raise the hood or tie a brightly colored piece of fabric (preferable red) to the vehicle antenna or hang it out the window. As long as you stay on main roads, your vehicle is likely to be spotted by rescuers so it is usually safer to stay in the vehicle than to set out on foot. It is very easy to get lost in wind driven snow, especially as hypothermia compromises your ability to think clearly. If a building is visible, be careful when making the decision to proceed on foot to take shelter there. Distances can be easy to misjudge when there is heavy snowfall and the effort required to get there through the snow may be far more than what is initially thought. You should run the vehicle about 10 min of each hour to keep warm. At night, leave the inside dome light on while the engine is running to increase the chances of being seen. Before starting the vehicle, make sure the snow is not accumulating around the exhaust pipe, leave one window on the downwind side of the vehicle open slightly for fresh air and to lessen the risk of CO poisoning. If there is more than one person in the vehicle, it is recommended that each person should take a turn resting while the other watches for rescuers. Keep moving around using small exercises, moving your arms and legs to maintain blood circulation to extremities."

Public Messaging for Those at Home

"If you are home during a winter storm, it is best to stay inside. To conserve heat, you may want to close off unused rooms of the home and place rolled up towels along the cracks at the base of the doors. If power is out and you use a generator or alternative heat sources, such as a fireplace or space heater, be sure they are vented properly to avoid CO poisoning. Stay well-nourished and hydrated and avoid excessive use of alcohol or caffeine. If you go outside to clear snow, make sure you stretch before going out and work slowly. Those who do not have a regular exercise program are particularly susceptible to a heart attack from overexertion. You should keep dry and if it is extremely cold, cover your mouth to protect your respiratory system. You should also be aware of the signs and symptoms of cold injury and quickly get dry and warm if those signs are observed. If the symptoms persist, seek medical care. If the sun is reflecting off the snow, there are increased risks for solar keratitis or snow blindness, and sunburn. Exposure should be limited and sun block and eye protection should be used."

A pet investigates her backyard transformed by more than 1 foot of snow during a rare October nor'easter storm in Connecticut. *Photograph by Seth Gardner–Gould courtesy of the Federal Emergency Management Agency (FEMA).*

Summary

Winter storms can be deceptively hazardous. Small accumulations of ice can make roads impassable and interrupt utilities. Low temperatures and cold winds can quickly cause injury on what may otherwise appear to be a pleasant day. The impact is most severe among vulnerable populations such as the very young, elderly, those with existing health conditions, and those with substance abuse issues. As with heat waves, winter weather morbidity

and mortality may never be fully characterized because it can exacerbate existing conditions resulting in fatal outcomes not always attributed to the weather. What may be the biggest challenge of severe winter storms is the loss of essential services when roads may be impassable resulting in the isolation of vulnerable populations. The basic elements of a prepared community are achievable with the proper level of community and individual awareness and the motivation of residents to look out for each other. A widespread loss of services during a major winter storm will quickly overwhelm available response resources and make neighbor to neighbor collaboration essential to reduce overall morbidity and mortality.

Websites

American Academy of Pediatrics, Winter Storm Tips. http://www2.aap.org/advocacy/releases/janwinter.htm.

American Red Cross, Winter Storm Preparedness. http://www.redcross.org/prepare/disaster/winter-storm.

Canadian Centre for Occupational Safety and Health, Cold Weather Worker Safety Guide. http://www.ccohs.ca/products/publications/cold.html.

Centers for Disease Control and Prevention, Emergency Preparedness and Response, Winter Weather. http://emergency.cdc.gov/disasters/winter/.

Centers for Disease Control and Prevention, Extreme Cold: A Prevention Guide to Promote Your Personal Health and Safety. http://www.bt.cdc.gov/disasters/winter/pdf/extreme-cold-guide.pdf.

Federal Emergency Management Agency, Winter Storms & Extreme Cold. http://www.ready.gov/winter-weather/.

National Ag Safety Database, the Ohio State University, Cold Weather Exposure. http://nasdonline.org/document/129/d001677/cold-weather-exposure.html.

National Institute of Occupational Safety and Health (NIOSH), Workplace Safety & Health Topics, Cold Stress. www.cdc.gov/niosh/topics/coldstress/.

National Oceanic and Atmospheric Administration (NOAA), National Weather Service. Brochure: "Winter Storms Deceptive Killers: A Guide to Survival", November 1991. http://www.nws.noaa.gov/om/winter/resources/Winter_Storms2008.pdf.

Occupational Safety and Health Administration, OSHA Offers Tips to Protect Workers in Cold Environments. www.osha.gov/html/cold_protection_2004.html.

Princeton University, Outdoor Action Guide to Hypothermia and Cold Weather Injuries. www.princeton.edu/~oa/safety/hypocold.shtml.

U.S. Army, Technical Bulletin TB MED 508, Prevention and Management of Cold-weather Injuries, April 2005. http://www.usariem.army.mil/assets/docs/publications/articles/2005/tbmed508.pdf.

U.S. Army, TRADOC Regulation 350–29, Prevention of Heat and Cold Casualties. http://www.tradoc.army.mil/tpubs/regs/tr350-29.pdf.

U.S. Search and Rescue Task Force. Hypothermia and Cold Weather Injuries. http://www.ussartf.org/hypothermia_cold_weather_injuries.htm.

References

Berko, J., Ingram, D.D., Saha, S., Parker, J.D., 2014. Deaths Attributed to Heat, Cold, and Other Weather Events in the United States, 2006–2010. National Health Statistics Reports; No 76. National Center for Health Statistics, Hyattsville, MD. Available at: http://www.cdc.gov/nchs/data/nhsr/nhsr076.pdf.

Danzl, D.F., Pozos, R.S., 1994. Accidental hypothermia. N. Engl. J. Med. 331, 1756–1760.

Houck, P.M., Hampson, N.B., 1997. Epidemic CO poisoning following a Winter storm. JEM 15 (4), 469–473.

Johnson, G., Levenson, M., January 27, 2005. 1-Month Snowfall a 113-year High. The Boston Globe. www.boston.com/news/weather/articles/2005/01/27/1_month_snowfall_a_113_year_high/.

Johnson, W., January 12, 2008. It Was Terrible. Springfield News-Leader. www.news-leader.com/article/20080112/NEWS01/801120381.

Kelly, N., Whittock, M.J., 1995. Heinemann History Study Units: Student Book. The Twentieth Century World, p. 17.

Missouri State Emergency Management Agency (SEMA), January 24, 2007. Situation Report. Winter Storm.

Oklahoma Department of Emergency Management (OEM), January 23, 2007. Situation Update 35, State/Federal Ice Storm Response Continues.

Reamy, B.V., 1998. Frostbite: review and current concepts. J. Am. Board Fam. Pract. 11, 34–40.

Simon, T.D., Soep, J.B., Hollister, J.R., 2005. Pernio in pediatrics. Pediatrics 116 (3), e472–e475.

U.S. Army (USA), 2005. Technical Bulletin TB MED 508, Prevention and Management of Cold-Weather Injuries. www.usariem.army.mil/download/tbmed508.pdf.

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