The Role of Applied Epidemiology Methods in the Disaster Management Cycle

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Disaster epidemiology (i.e., applied epidemiology in disaster settings) presents a source of reliable and actionable information for decision-makers and stakeholders in the disaster management cycle. However, epidemiological methods have yet to be routinely integrated into disaster response and fully communicated to response leaders. We present a framework consisting of rapid needs assessments, health surveillance, tracking and registries, and epidemiological investigations, including risk factor and health outcome studies and evaluation of interventions, which can be practiced throughout the cycle. Applying each method can result in actionable information for planners and decision-makers responsible for preparedness, response, and recovery. Disaster epidemiology, once integrated into the disaster management cycle, can provide the evidence base to inform and enhance response capability within the public health infrastructure. (*Am J Public Health.* 2014;104:2092–2102. doi:10.2105/AJPH.2014.302010)

The public health role of preparing for and responding to emergencies has expanded in the face of massive impacts from recent disasters. The application of epidemiology in disaster settings, also known as disaster epidemiology, can provide actionable information for use by policymakers, planners, incident commanders, decision-makers, and affected community members (Box 1). Although disaster epidemiology may date to the 1970s, descriptions of the role of the epidemiologist in disaster response to the 1980s, and overviews of epidemiological methods in public health and disaster response to the 1990s, systematic use of the term "disaster epidemiology" has helped to establish the discipline as a formal subset of epidemiology and to spur its application today.[4–9]

Specifically, disaster epidemiology encompasses rapid needs assessment, surveillance, tracking, research, and evaluation, executed in response to a large-scale emergency or disaster.[2,3] These activities assist decision-makers by providing situational awareness for characterizing an incident's immediate effects on human health, short- and long-term consequences, and impacts of targeted actions and interventions. For example, information generated by public health surveillance is useful for describing the types and severity of postdisaster injuries and illnesses and causes of mortality. Surveillance systems may rapidly detect outbreaks or clusters of illness in shelters for displaced populations or in base camps housing response workers. Epidemiological methods are used for measuring disaster-related impacts on affected populations and demands on health care delivery systems, as well as evaluating the effectiveness of health interventions and disease control efforts after an event. Evaluation of a response can also improve future public health preparedness planning. Disaster epidemiology provides a systematic and robust mechanism to gather accurate data to inform emergency responders.

CONTEXT FOR APPLIED EPIDEMIOLOGY IN DISASTERS

Disasters are complex situations in which the consequences of an event are beyond the capability of an affected jurisdiction to respond effectively, generally of 2 types:

1. Natural: hydrometeorological (e.g., flooding, tornados, hurricanes, ice storms); geological (e.g., earthquakes, volcanic eruptions); or biological (e.g., influenza pandemics) or
2. Manmade: unintentional or deliberate (e.g., terrorist attacks including bioterrorism, chemical spills, radiation releases, wildfires, engineering failures, civil conflicts).[5,10,11]

Nearly every large-scale disaster carries substantial public health risk and requires a response that addresses immediate effects of the disaster on a population (e.g., mass casualties and severe injuries, lack of shelter in severe weather, acute illness in biological disasters), as well as disaster-caused secondary effects (e.g., carbon monoxide [CO] poisoning because of improper operation of fuel generators, inadequate safe water as a result of disruption of water treatment activities, exposure to chemical spills).

Epidemiological methods have been developed to assess the scope of public health problems in communities. These methods provide information about the effects on people's physical and mental health as well as social and community needs for life-saving or life-preserving decisions, controlling the spread of rumors, gauging medical needs, and assessing impacts on health care systems.[6] Rapid needs assessments provide a quick cross-sectional overview of damage estimates and community needs.[7] Morbidity and mortality surveillance assist in identifying the health burden from an event for targeting response efforts where most needed.[8,12] Epidemiological investigations characterize risks of adverse health outcomes and inform the design and implementation of appropriate interventions, including studies that evaluate the effectiveness of intervention and recovery efforts to yield lessons learned. Finally, registries assist in tracking medium- and long-term consequences

Key Disaster Epidemiology Terms

Epidemiology: The foundational science of public health, epidemiology is the study of the distribution and determinants of illness, injury, disability, and death in specified populations and the application of this study to minimize these outcomes. "Distribution" refers to analysis by time, place, and classes of persons affected. "Determinants" are the physical, biological, social, cultural, and behavioral factors that influence health.

Epidemiological methods: Scientific approaches used in the practice of epidemiology, including surveillance, observation, hypothesis testing, analysis, and studies.

Applied epidemiology: The application of epidemiological methods to characterize the nature and dynamics of the health consequences of an event. The information generated by applied epidemiology can directly inform decision-making on the behavioral, clinical, and environmental actions that can mitigate illness, injury, disability, and death in a disaster setting.

Disaster: A defined event in space and time that threatens human health and exceeds the local capacity to respond, calling for outside assistance. A disaster is generally classified as a naturally occurring meteorological, geological, or biological event, or a manmade (unintentional or deliberate) event with mass casualty potential caused by biological, chemical, radiological, or nuclear forces, or by transportation incidents, engineering failure, or civil conflict.

Disaster epidemiology: The practice of applied epidemiology during a disaster to generate scientifically sound information about the health effects of the disaster and to inform decisions about resource allocation and other mitigating actions.

Public health surveillance: The systematic collection, analysis, and interpretation of deaths, injuries, illnesses, and exposures to provide actionable information about any adverse health effects related to a disaster event in a community. It allows us to assess the human health impacts of a disaster and evaluate potential problems related to planning and prevention.

Environmental monitoring: The collection of environmental hazard data that can be linked to exposure and health effects in people affected by the disaster.

Registries: Databases that allow for the longitudinal observation of exposed persons after a disaster event to identify medium- to long-term health consequences of the disaster. Registries inform the need for ongoing care or public health measures as well as developing health education and disease prevention measures.

Source. Last,[1] Gunn,[2] and Lechat.[3]

of a disaster. In combination, these methods can contribute to a greater understanding of the public health consequences of the immediate event and beyond and can enhance planning, preparedness, and mitigation for future disasters.

Successful applications of epidemiology in disaster settings are largely contingent on recognizing opportunities to collect actionable information for developing or evaluating interventions to preserve health and save lives. Examples include identifying risk factors and prevention measures for minimizing injuries and deaths from CO poisoning, identifying complications from crush injuries of earthquake victims, and informing strategies for preventing unintentional drowning during floods and hurricanes.[13–15] Evaluating the effectiveness of intervention strategies helps to identify mitigating actions that should be incorporated into disaster planning and preparedness.

Although the impact of disaster epidemiology is potentially far-ranging, much remains to be done to develop a scientific knowledge base for the discipline. Disaster epidemiology is an evolving field that integrates various data sources, and technological and geospatial resources to increase the accuracy and timeliness of information collected for use by emergency planners and incident managers.[16]

As the national organization supporting epidemiology in state, tribal, local, territorial, and federal public health agencies, the Council of State and Territorial Epidemiologists (CSTE) assembled a subcommittee of practitioners from diverse fields of applied epidemiology to discuss the use of epidemiology in the disaster management cycle. During 2010 to 2013, this subcommittee held 4 workshops in Atlanta, Georgia, where representatives from public health agencies and academic institutions across the country and from the Centers for Disease Control and Prevention (CDC) discussed a framework for applying disaster epidemiology to meet information needs facing emergency preparedness and public health officials and formulated 3 overarching goals[9]:

1. Strengthen the nation's capacity to respond to public health emergencies by integrating applied epidemiology into public health preparedness, response, and recovery efforts.
2. Educate response planners, incident commanders, and others in leadership positions to better understand the foundational role of applied epidemiology in response planning, execution, and recovery.
3. Identify a common set of capabilities needed to support disaster epidemiology activities during emergency response situations.

In line with these goals, the subcommittee agreed on 6 objectives:

1. Identify key disaster epidemiology personnel, their roles, and ranges of responsibilities in the disaster management cycle.
2. Identify examples of disaster epidemiology activities that are currently being implemented at state, tribal, local, territorial, and federal levels.
3. Identify ways to activate and implement disaster epidemiology activities during specific phases of the disaster management cycle.
4. Identify ways to better inform public health partners (e.g., emergency response agencies, social service providers, private sector including construction and housing industries) of the benefits of disaster epidemiology capabilities in public health departments so they may be used in overall preparedness, response, and recovery efforts.
5. Identify common, potentially standardized, emergency response information needs throughout the disaster management cycle that can be met by disaster epidemiology skills and activities.
6. Identify and standardize epidemiological skills, common capabilities, and tools that are applicable to emergency response.

The national workshops focused on 4 key methods frequently employed in disaster settings:

1. Survey techniques (e.g., rapid needs assessments),
2. Public health surveillance and tracking systems (e.g., determining the health burden of affected communities and response workers during response and recovery phases),
3. Epidemiological investigations and studies (e.g., observational or analytic studies of the public health impacts of an incident or the effects of prevention or recovery efforts), and
4. Longitudinal observation (e.g., person-centric observations for potential long-term consequences resulting from illness, injury, or exposures during the immediate response).

We describe the application and contribution of these methods in the disaster management cycle and identify possible roles for stakeholders that might optimize core public health disaster preparedness and response activities.

CONCEPTUAL MODEL FOR DISASTER EPIDEMIOLOGY

We began with a framework developed by the World Health Organization for a disaster's phases and a community's response (Figure 1).[17] The predisaster period, occurring between disaster events (i.e., before the next disaster) entails work to prevent or mitigate the impact of a future disaster. Examples include physical infrastructure activities (e.g., strengthening levies to prevent flooding, constructing tornado shelters), policy efforts (e.g., establishing and enforcing disaster-resistant building codes), and preparedness activities (e.g., arranging volunteer deployment, training volunteer search and rescue, organizing systems for distributing supplies to field hospitals).

The disaster period occurs when the disaster strikes: disasters can unfold in seconds (e.g., tornado strike, plane crash), over hours or days (e.g., hurricane, wildfires, dam break), or even months to years (e.g., drought, famine). During this time, responders may conduct search and rescue, evacuate people, deliver emergency care, or provide shelter and food; concurrently, public health responders implement targeted or enhanced surveillance. Response, recovery and rehabilitation take place in the postdisaster period, when a return to predisaster conditions or "normalcy" is under way. Depending on the nature and severity of the disaster, fully operational predisaster societal activities (e.g., access to water, food, energy) may take years to restore.[18]

Source. Wisner and Adams.[17]

FIGURE 1—The disaster management cycle.

To develop a conceptual model, we identified specific activities appropriate for each phase of the cycle (Figure 2). Because emergency managers require accurate information to make decisions, epidemiologists may assist by conducting assessments to characterize the scope of a problem, identifying risk factors associated with mortality and morbidity, developing intervention strategies, and evaluating the effectiveness of interventions. Just as there is overlap among the 3 phases, activities associated with each phase may cross over as well.

Key disaster-related activities employing epidemiological methods include rapid needs assessments, health surveillance, tracking systems, epidemiology investigations and studies, and registries.

Rapid Needs Assessments

Rapid needs assessments employ survey sampling techniques in field settings to rapidly determine the health status and basic needs of an affected community in a statistically valid manner for actionable response.

Because emergency response often requires immediate information on health status and community needs, such information must be

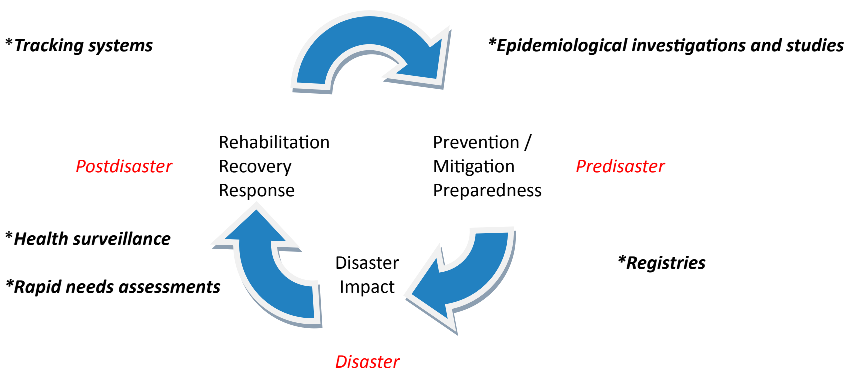

FIGURE 2—Disaster epidemiology actions and the disaster management cycle.

gathered in the field and analyzed quickly. An assessment is initiated and completed, ideally within 72 hours. Speed is critical because circumstances often change quickly with time; outdated information may be of little use to response personnel.[19,20] Assessments may also be conducted periodically within days, weeks, or months after the disaster, depending on objectives. Examples of useful data from rapid needs assessments include identifying health hazards related to lack of basic utilities and medical care in Texas after Hurricane Ike (2008), estimating the prevalence of mental health symptoms in Alabama and Mississippi 1 year after the Gulf Coast Oil Spill (2011), and evaluating routine environmental health inspections in North Carolina (2003–2010).[21–23]

Rapid needs assessments stem from assessments of community immunization coverage and developments by the World Health Organization's Expanded Programme on Immunization in the 1970s and 1980s. The primary method today allows for representative information to be rapidly collected from disaster-affected communities.[24,25] This approach has been adapted by CDC to assess health status and community needs, known as the Community Assessment for Public Health Emergency Response (CASPER),[26] where household-level surveys provide information about health status and community needs in a quick, low-cost although sometimes labor-intensive manner that can be implemented within days of a disaster event.

CASPER typically uses 2-stage cluster probability sampling to select a representative group of 210 households to be surveyed from affected areas.[26] Intended for teams with minimal training, the surveys are typically 1 to 2 pages in length and are designed for rapid data entry, analysis, and report writing. The method assumes that selected households are accessible and that a household member is available to respond to questions at the time of the survey.

Interview teams may also disseminate health and safety messages relevant to the incident (e.g., boil water advisories). More recently, CASPER has evolved into nonemergency community-based assessments to gauge household preparedness, underlying vulnerabilities, and community perceptions regarding hazards and emergencies, as well as vaccine compliance during the influenza A pandemic.[27,28] Many state health departments now use CASPERs for disaster and nondisaster situations[21,23,27–32] and provide technical assistance under the Emergency Management Assistance Compact for mutual aid.[33]

Health Surveillance

Public health surveillance techniques characterize the health burden of the disaster, target response efforts, identify interdisaster outbreaks or clusters of conditions, and describe the distribution of adverse health events on specific populations.

Health surveillance in disaster settings is the systematic collection, analysis, interpretation, and dissemination of health data to characterize the burden of disaster-related morbidity and mortality in an affected community and among emergency responders.[34] Tallies of specific illnesses, injuries, and deaths measure the scope and magnitude of a disaster and the evolving conditions that follow. Timely information about direct and indirect adverse health outcomes may inform decision-making and planning by incident managers and public health authorities.[35,36]

Different types of disasters may be associated with different types of adverse health outcomes. For example, during widespread power outages—often after hydrometeorological disasters—CO poisoning may result from improper use of gasoline- or propane-powered generators.[13] In geological disasters, such as earthquakes, injuries commonly result from collapsing walls, broken glass, and falling objects.[37] During clean-up, outcomes such as chain saw–related injuries, electrocution, and excessive exposure to extreme temperatures have been reported.[38] Motor vehicle crashes might be expected because of re-routing of traffic and damaged or destroyed signage. Animal bites from displaced domestic animals and wildlife have been reported after earthquakes, floods, and hurricanes.[39] Although early prevention messages can reduce injury, timely surveillance initiation can inform control measures.

Typical surveillance activities initially focus on injuries and illnesses treated in local hospitals and health care clinics. Because local health care facilities may be destroyed or incapacitated, functioning sites may be operating at or beyond peak capacity, creating a challenging environment for surveillance. Additional or enhanced surveillance is often initiated in shelters, first aid stations, and field decontamination posts, along with syndromic surveillance in emergency departments, poison centers, and emergency medical facilities. Health departments may seek to become familiar with available data sources and to better understand their statutory authorities for prompt implementation of surveillance systems.[40–44]

Understanding the severity and scope of a disaster may dictate whether surveillance should be established or enhanced. Such surveillance "thresholds" may consider several factors: location of the affected population (residence or shelters), status of the public health infrastructure and its capacity to conduct surveillance, and status of the health care delivery infrastructure where injuries and illnesses are treated. These thresholds can be useful guidelines for implementing surveillance, but the nature of disasters requires flexibility when one is considering specific strategies. For example, winter storms striking northern Oregon in 2007 led to major power outages disrupting communication media ordinarily used for surveillance. Unable to conduct household surveillance, epidemiological strike teams visited area hospitals to conduct case reviews and collect emergency department and admission data.[45]

Various resources are available for different disaster settings. Large-scale chemical incidents pose challenges for identifying exposed populations, health effects, and impacts on the health care system, as well as drawing lessons during the response. The Agency for Toxic Substances and Disease Registry maintains an Assessment of Chemical Exposures toolkit with survey forms that are readily adaptable for different types of chemical incidents.[46] A need to monitor physical and behavioral health impacts among incident responders led to the development of the Emergency Responder Health Monitoring and Surveillance by CDC's National Institute for Occupational Safety and Health. After the Gulf Oil Spill in 2010, the National Institute for Occupational Safety and Health used the Emergency Responder Health Monitoring and Surveillance to track disease and injury among first responders, contractors, and volunteers, and implemented prevention measures on the basis of those data.[47]

Initially established in 2006 as the Disaster Surveillance Work Group in response to lessons learned from Hurricane Katrina, CDC's Disaster Epidemiology Community of Practice develops and evaluates standardized surveillance tools to ensure comparable data among disaster-affected jurisdictions on the basis of available personnel and resources. To date, the Disaster Epidemiology Community of Practice, comprised of experts from CDC centers, federal agencies, and state and local health departments, has developed, distributed, and evaluated morbidity and mortality surveillance tools for responses to Hurricane Gustav (2008), the earthquake and tsunami in American Samoa (2009), and the Gulf Oil Spill (2010).[48,49]

Health care facility surveillance. Initial surveillance during disasters often relies on existing systems where possible. Hospitals, clinics, provider offices, and laboratories are typically the primary sources of initial surveillance data during a disaster or emergency. When there is a stable, functioning health care infrastructure (e.g., during the 2009 influenza A H1N1 pandemic), existing systems will provide the most reliable and timely data.[50,51]

Monitoring utilization at medical facilities helps public health authorities characterize service demands and available emergency and inpatient resources. It also enables authorities to direct the transportation of patients to locations with the best capacity and resources to meet the demand for care. Provider reporting often reveals early information about unfolding incidents and outbreaks.[52] Poison control centers may document concerns about chemicals or products from clinicians and the public at large.[53]

However, to establish situational awareness quickly, routine data collection may need to be enhanced by active surveillance. Under normal circumstances, infectious disease surveillance reports typically come to local or state health departments passively via laboratory reports and provider reporting.[54] When a public health emergency is declared, public health officials may opt to contact health care facilities treating evacuees to request active reporting on certain conditions or syndromes related to the disaster.[55] During the influenza A H1N1 pandemic, for example, many states requested immediate reporting of any pregnant woman hospitalized with influenza-like symptoms—rather than waiting for laboratory confirmation of influenza A H1N1—to quickly assess relationships between pregnancy and adverse influenza outcomes.[50]

External surveillance for situational assessment. When the health care infrastructure is compromised, going outside existing reporting frameworks may be necessary. Quick assessment of the viability of the health care system to adequately provide services in the midst of a disaster is a vital responsibility. In disasters involving substantial injury and death, such as violent tornadoes, health care facilities, local clinics, pharmacies, and others may be partially incapacitated or destroyed. Rapidly collecting information on the status of affected health care delivery systems—including home health agencies, dialysis centers, and medical equipment suppliers—can provide decision-makers with critical information for resource allocation to protect vulnerable populations, such as those dependent on dialysis, supplemental oxygen, or insulin. If roads are impassable or electricity unavailable and health care facilities cannot provide needed supplies or services locally, a second wave of morbidity and mortality may arise in the days following the actual disaster event. Active surveillance can identify service gaps so that solutions may be addressed.

Surveillance activities may be challenged by the lack of denominator data or complete counts, making it difficult to construct useful prevalence or incidence rates. However, even if only frequencies are available, surveillance data can track disaster-related disease and injury trends when contrasted with a reasonably comparable time period.

Syndromic surveillance. Electronic surveillance of emergency department data on chief complaints and clinical diagnoses is another way to examine patterns of illnesses and injuries before, during, and after emergency events. The US Department of Health and Human Services' BioSense 2.0 provides a common electronic health information system that can detect morbidity patterns in near real time.[56–58] After the 2010 Gulf Oil Spill, BioSense monitored 21 syndromes to identify potential disease outbreaks or harmful effects of exposure to oil or other chemicals.[59] Locally developed systems are increasingly used by states, such as the Louisiana Early Event Detection System, EpiCenter (Ohio), Early Event Detection Systems (Texas), and the Electronic Surveillance System for the Early Notification of Community-Based Epidemics used by Florida, Virginia, and military health care facilities.[60–65]

Shelter surveillance. Shelter occupants represent a segment of the community having potentially significant physical and mental health problems.[40,66] Their composition is largely influenced by the nature of the disaster. For example, in a sudden large-scale event such as a massive earthquake, many people from all socioeconomic categories may need assistance, whereas in hurricanes, those who are unable or unwilling to evacuate (often the poor and other vulnerable groups) will likely constitute the majority of displaced people.[67] Shelters vary in size and in length of operation on the basis of community needs; they may house a small number of displaced people for a few days or tens of thousands of evacuees for weeks to months.

No clear criteria have been established for when to initiate and cease surveillance in shelters. Unless their operation is planned for only 1 to 2 days, some form of surveillance is advisable—regardless of shelter size—to identify disaster-related morbidity, document special needs such as chronic conditions, and help ensure that required resources are available for evacuees.

In some cases, initial health information may be gathered on sheltered individuals during the intake process or as soon as feasible after intake. Information might include chronic and acute health problems, medications, and special needs. A balance of detail and simplicity is necessary, because collecting accurate and complete health information often occurs under conditions of duress and anxiety. A real-time, searchable list of evacuees present in the shelter can be ideal both for public health purposes and to reunite family members who may be separated during the disaster event.

Active, passive, and syndromic surveillance approaches may be used in shelters. The best approach will depend in large part on the size and makeup of the shelter population and the information requirements of emergency managers and public health officials. During sheltering operations, health surveillance may need to adapt to the needs of responding authorities, situational dynamics, the changing makeup of the shelter population, and variations in population numbers. Active surveillance, where staff interview sheltered individuals to document new health issues on a regular basis, is considered the most desirable and successful approach.[68,69] Shelters with limited resources to conduct active surveillance may choose to implement a more passive approach, which may result in diminished accuracy and completeness of the reported illness data and delay identification of emerging needs or outbreaks. Hence, a blend of surveillance approaches may be adapted to shelter needs. Regardless of the approach chosen, data analysis must be timely and reports readily available to facilitate response actions.

Examples of shelter surveillance have been documented after Hurricane Katrina struck Louisiana in 2005 and resulted in more than 24 000 evacuees housed for weeks to months at a shelter in Houston, Texas.[70] Outbreaks of noroviruses were reported among shelter evacuees in Colorado, Georgia, Louisiana, Mississippi, Tennessee, and Texas in the aftermath of Hurricane Katrina.[40–44] Gastrointestinal illness was most commonly reported; laboratory-confirmed pathogens included *Salmonella*, nontoxigenic *Vibrio cholerae*, *Vibrio vulnificus*, and *Vibrio parahaemolyticus*. A large cluster of methicillin-resistant *Staphylococcus aureus* was also detected in a Dallas, Texas, shelter.[43]

Tracking Systems

Tracking systems refer to the collection and integration of data from environmental monitoring, exposure, and health effects in people over time. Information is typically gathered during response and recovery phases, and helps identify needs for ongoing care or public health interventions and informs the development of health education and disease prevention measures.

Identifying and locating people who likely risked exposure, especially to chemical hazards, as early as possible is often the key to minimizing immediate adverse outcomes and to elucidating the range and severity of adverse outcomes among exposed populations. Finding those who were present during an incident may be logistically difficult, as people will likely leave the site if they are able. Thus, gathering basic identifier and contact information from exposed persons wherever they can be found (e.g., clinics, hospitals, decontamination sites, shelters), including formal responders, contractors, and volunteers who may also have been exposed to a particular hazard of interest, are important for facilitating longer-term follow-up, as needed.[47]

In a more specific application, environmental public health tracking is the ongoing collection, integration, analysis, interpretation, and dissemination of data from environmental hazard monitoring and related surveillance of human exposures and health outcomes. It is performed to protect communities by providing information that can be used to plan, apply, and evaluate public health actions to prevent and control environment-related diseases,[71] and may be particularly useful for addressing mid- to long-term outcomes in response and recovery.

Environmental public health tracking can be used to identify environmental hazards, human exposures, and resulting adverse health outcomes related to disaster situations; pinpoint where hazards and adverse health outcomes are occurring; measure relationships among hazards, exposures, and health sequelae; and target and measure the impact of intervention and mitigation strategies. By integrating hazard and health data, it provides an evidence base for future response and forms the basis for deciding whether and the extent to which continued tracking is needed in the short or long term. In 2009, CDC launched the National Environmental Public Health Tracking Network, the potential of which has yet to be tapped for postdisaster response. To date, at least 24 city and state health departments have implemented local environmental public health tracking networks that feed into this national network.[71]

Epidemiology Investigations and Studies

Postdisaster epidemiological investigations and studies employ descriptive and analytical techniques to better understand issues resulting from needs assessments or surveillance, and to establish determinants for adverse health outcomes so that interventions may be designed and implemented to prevent further morbidity and mortality. As examples, after a case series of laboratory-confirmed CO-poisoning patients and a community-based telephone survey following a severe ice storm–caused power outage in Maine (1998), a case–control study of households using specific CO sources found that gasoline-powered generators were the major CO source and generator location an important risk factor for CO poisoning.[13] An increase in gastrointestinal symptoms was observed among community members who had contact with floodwater after massive flooding occurred in the Midwestern United States (2001).[72] A cross-sectional study following Hurricanes Katrina and Rita (2005) in New Orleans, Louisiana, found a positive association between respiratory symptoms and exposure to water-damaged homes and determined that respirator use protected individuals against symptom exacerbation when inside water-damaged dwellings.[73]

Studies may also use exposure data to measure risk factors. Cohort and case–control studies addressed risk factors for traumatic injury after an earthquake in Northridge, California (1994),[14,74,75] in which findings identified peak ground acceleration, perceived shaking intensity, building characteristics, and individual characteristics as factors in injury risk. Several case–control studies following tornadoes in Texas and Oklahoma (1979, 1999) identified risk factors for death and injury.[76–78] One study examined risks among occupants fleeing their homes in motor vehicles versus those who remained within structures, raising concerns about the relative safety of occupying motor vehicles during tornados.[79]

Although typically conducted postdisaster, investigations and studies may be implemented long after life-saving emergency measures have been completed and issues requiring formal study have been identified (e.g., as relating to physical, environmental, mental, or social conditions affecting public health). Findings from a longitudinal cohort established after the World Trade Center attack (2001) of survivors exposed to airborne contaminants to document their physical and mental health showed that those exposed to the dust cloud had elevated risks for developing new-onset asthma and posttraumatic stress disorder 5 to 6 years after the incident.[80]

Evaluation and economic methods may be used to assess processes or outcomes from relief and recovery programs for improved decision-making and delivery of services. For example, evaluation of post–Hurricane Katrina grief and trauma interventions for children showed a significant decrease in measures of posttraumatic stress but no differences between group and individual treatments, suggesting that either treatment modality may be effective.[81] Findings from evaluation also can indicate successes and failures of response programs, identify data collection efforts for prompting appropriate and adequate actions, and can inform cost-effective strategies.[6]

Epidemiological investigations and studies serve other purposes. (1) They can validate or refute specific behavioral responses and safety messages. For example, advice to take cover under highway overpasses when tornadoes approach has been found on printed government materials, but could increase the risk of injury or death by encouraging individuals to seek shelter, rather than sheltering in place.[82] (2) They can enhance communication strategies by identifying effective languages and media for promoting behavioral change during warning, response, and recovery phases. (3) They can aggregate information from multiple disasters to identify commonalities or patterns at a broader level. Lessons learned in retrospect may be applied to successfully managing future incidents.

Although most health departments have few resources to conduct epidemiological studies, their role in disaster response—including conducting rapid needs assessments and implementing surveillance activities—is critical to the subsequent establishment of larger-scale studies. Partnerships among public health agencies, other government entities, nongovernmental organizations such as the American Red Cross, and academic institutions are essential to maximize information collected under potentially fleeting conditions and to the ultimate use of these data for action.

Although methods for assessments and surveillance have improved over the years, the application of standard epidemiological methods for disaster research has not been widely examined.[83] Descriptive studies have generally been used in field investigations simply because they are convenient and easy to implement during an investigation's average 2- to 3-week duration.[6] Although traditional study designs, such as cohort, case–control, and cross-sectional methodologies, are likely to be broadly applicable to disaster scenarios, variations on these designs have not been extensively considered.[6] Any variation, however, must be tailored for field settings where disaster-affected populations might be highly mobile.

Many opportunities exist for epidemiological studies and development and application of tools. On the basis of this review, some areas for future work include

1. Identifying reliable sources of existing baseline data so excess numbers of new cases associated with an emerging incident can be gauged;
2. Synthesizing data from multiple disaster responses, such as CASPER investigations or syndromic surveillance, so community planners may better anticipate population needs;
3. Evaluating the use of new technologies to collect data in real time (e.g., electronic medical records, geographic information systems tools, smart phones, and telemedicine) and applying those technologies as appropriate;
4. Evaluating different methods of data collection to determine which is most efficient for specific types of disasters (e.g., paper and pencil may be the most efficient in some instances);
5. Capitalizing on initial findings from field assessment or surveillance to generate hypotheses for research and connecting fieldwork and academic research so research questions may be posed immediately from field observations;
6. Making effective use of biomonitoring data and other laboratory findings to quantify human exposures to environmental toxicants, where applicable;
7. Involving more first responders in data collection activities (e.g., integrating passive geographic information systems technologies into response efforts);
8. Applying lessons learned from past disasters in a timely manner (e.g., disseminating warnings about the risk of CO poisoning posed by gasoline- or propane-powered generators soon after a power outage has begun);
9. Conducting cost-effectiveness studies to optimize disaster response and resource utilization; and
10. Assessing the effectiveness of syndromic surveillance, specific case definitions, and data sources for detecting various health outcomes (e.g., feasibility of evaluating mental health outcomes by using syndromic surveillance).

Registries

As specialized surveillance, registries employ structures and processes for documenting environmental hazards and exposures for longitudinal patient observation before or after epidemiological studies and investigations. Information from registries helps to identify medium- to long-term health consequences, and needs for testing or care, and clarifies the link between exposures and health outcomes.

In some cases, resulting illnesses, injuries, or disabilities—including emotional trauma—may not be recognized or resolved in the immediate postdisaster period. Following these populations over months, or years, through the course of illnesses, injuries, or disabilities, can help public health officials understand the extent to which populations are affected by a disaster, and identify ways to improve disaster response in future emergencies. Integrating design, measurement, and analysis in postdisaster mental health needs assessment tracking surveys has been undertaken by the US National Institute of Mental Health.[84] If the risk for developing serious, delayed illness (e.g., cancer, mental illnesses, chronic lung disease) is high, it may be appropriate to enroll people into a formal public health registry and observe outcomes over an extended period. In addition, population-based health information may be obtained from registries, such as Surveillance Epidemiology and End Results registry, which may provide useful comparisons for patterns of specific diseases.[85] Knowing the type, range, frequency, and risk factors of adverse health outcomes, including disabilities and psychosocial sequelae that may arise weeks to years after the initial incident, may be useful for health planning. Registries build on information generated by rapid needs assessments and tracking systems mentioned previously.

Disaster registries follow groups of people exposed during an incident and allow health professionals and public health officials to investigate possible trends in illnesses that may not be evident at the time of the disaster. They may elucidate long-term health effects of the incident and improve efforts to save lives and reduce injuries in future crises.[86] Disaster registries established following the Oklahoma City bombing in 1995 and after the World Trade Center attacks in New York City in 2001[87,88] assisted in tracking survivors, responders, and recovery workers who experienced potentially adverse exposures while working at disaster sites. Rapid identification of those at risk helps to accurately enumerate and characterize exposed populations and may minimize subsequent bias resulting from potentially selective enrollment of either the sickest or healthiest portions of the cohort.[89]

Registries are more formal and require regularly observing groups of specific individuals over a longer period of time, perhaps years.[86,90] They aim to document health outcomes after exposures during larger-scale incidents through follow-up interviews or surveys, clinical examinations, and laboratory tests. Because they are often costly and complex, registries may be established when needs are well-defined. As an example, a 2001 post–World Trade Center attack registry continues to follow thousands of people who were involved in incident response and recovery and who were likely exposed to a variety of hazards for potential health effects and long-term care.[91–94] The decision to establish this registry containing almost 70 000 people was made almost 3 years after the incident, and many exposed persons were not identified or were lost to follow up. To aid in developing registries, the Agency for Toxic Substances and Disease Registry has developed a Rapid Response Registry, a brief survey instrument developed to collect data needed to form a registry of persons exposed or potentially exposed to chemical, biological, or nuclear agents from a disaster.[95]

CONCLUSIONS

Epidemiology-based activities can enhance situational awareness during an emergency and contribute to better understanding, resource allocation, and messaging during and after the event. Disaster epidemiology activities—rapid needs assessments, surveillance, registries, investigations, and studies—can be applied routinely throughout the disaster management cycle to provide actionable information about health status and resource needs among communities and workers to incident managers and other stakeholders. Epidemiological information supplied in real time during disaster events ultimately contributes to saving lives and reducing morbidity and mortality.

The CDC's Office of Public Health Preparedness and Response recently included "public health surveillance and epidemiological investigation" as 1 of 15 public health preparedness capabilities[96] outlining national standards for state and local health departments funded under CDC's Public Health Emergency Preparedness cooperative agreements.[97] This inclusion may provide impetus for the expanded use of disaster epidemiology in incident response.

Although disaster epidemiology has been linked to research,[6,98,99] it is essentially applied public health practice because findings from postdisaster investigations tend to define the nature of response and recovery. As such, the evidence indicates that it would be effective if made an integral part of the disaster management cycle. Despite different purposes and end results, both disaster-related research and public health practice seek to restore public health status in the aftermath of disasters, improve health conditions, and sustain the health and emergency management infrastructure so communities may be resilient and adaptive in future events.

On the basis of the evidence presented at the workshops, several activities fit within the traditional roles and responsibilities of participating agencies, and further clarify and build the role of applied epidemiology in the disaster management cycle:

For CSTE,

1. Inventory state and local health departments with experience in disaster epidemiology.
2. Create opportunities for disaster epidemiology by developing guidelines for health departments and through partnerships with academia, CDC, and other institutions.
3. Examine barriers for implementing disaster epidemiology within health departments.
4. Provide guidance on the appropriateness and timeliness of each epidemiological activity.
5. Build institutional capacity by offering training in disaster epidemiology: conducting CASPERs, implementing surveillance and tracking activities, an emergency responder health monitoring and surveillance system, training for improving responder safety and health, and developing a priori hypotheses for applied research.

For state, local, and tribal health departments,

1. Examine and overcome policy barriers for implementing disaster epidemiology.
2. Link with emergency management to identify mutually useful information during response and recovery.
3. Rapidly disseminate and translate findings and recommendations from assessments, surveillance, and investigations for local emergency management authorities.
4. Partner with academic institutions to conduct studies in postdisaster settings.
5. Identify sources of baseline data for targeted conditions so changes can be readily identified during an incident.
6. Establish protocols for data collection and sharing within the jurisdiction.
7. Obtain and maintain staff capacity and capability in disaster epidemiology.

For CDC,

1. Expand capabilities for disaster epidemiology by requiring disaster epidemiology capacity building as part of grant programs, such as those managed by CDC's Office of Public Health Preparedness and Response, to bring epidemiological investigations into each phase of the public health preparedness cycle.
2. Determine research gaps and facilitate exchanges between subject matter experts and researchers. Develop hypotheses before an event and incorporate them into the command structure of a response to an event. Develop questions of interest: What are we trying to understand? What are we investigating? What gaps need to be identified to reduce risks from disaster events?

3. Develop a central location (e.g., Web site) to document promising practices, such as surveillance strategies, model forms, helpful advice, and after-action reports and evaluations that could inform decisions about surveillance activities implemented in response to a disaster.
4. Prepare procedural requirements before field investigations, as appropriate: human participants review of protocols, compliance with the Office of Management and Budget Paperwork Reduction Act, and protection of privacy or assurance of confidentiality.
5. Develop a set of target capabilities specific to disaster epidemiology.
6. Remain involved in all phases of a response, as appropriate.
7. Create adaptable, Web device tools to support real-time disaster epidemiology practice in any disaster scenario.

For academic institutions,

1. Link with CSTE and state and local health departments to determine their needs in postdisaster settings.
2. Link with disaster responders to identify information needs to improve postdisaster public health and emergency management.
3. Validate information developed by CDC, CSTE, and state and local health departments to ensure generalizability of results and best practices, to the extent possible.
4. Develop and sustain the research component of disaster epidemiology (e.g., synthesis of information from rapid needs assessments, syndromic surveillance, and investigations related to risk factors for death, illness, and injury).
5. Develop evidence-based methods, tools, and practices, such as thresholds and trigger points for decision-making (e.g., conditions for conducting surveillance, analysis of surveillance data, sampling applications from CASPER technology). ■

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Contributors

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