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History of Disaster Epidemiology: 1960–2015

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BACKGROUND

Studies of the impacts of natural and man-made disasters have been undertaken since the 1950s and 1960s, growing out of the study of evacuation planning and research on wartime relocation following World War II, and later, concerns about nuclear attacks or accidents (Tierney, 2007). Early studies were primarily descriptive and based mostly on survey data collected following disasters. Surveys tended to rely on self-reported impacts and the time frames in which data were collected varied from immediately postdisaster to months after the event (Adams & Adams, 1984). These early studies were wide-ranging with regard to disaster type, including both acute (e.g., hurricanes, flash floods, and earthquakes) and more chronic types of emergencies (winter storms, droughts, and volcanic activity) (Adams & Adams, 1984; Erikson, 1976; Glass, O'Hare, & Conrad, 1979; Killian, 1954; Spencer, Romero, & Feldman, 1977).

From the beginning of disaster research, the methods used were “hardly distinguishable” from the methods used in everyday public health and social science research (Mileti, 1987, p. 69). However, the circumstances, under which the methods were employed, were very different and varied depending on the phase of the disaster process that was being studied. For example, immediately after a disaster, it may be more difficult to develop hypotheses, design reliable studies, recruit appropriate controls, or locate subjects (Killian, 1956). Delays associated with obtaining Institutional Review Board approval of research protocols may hinder the immediate collection of data in the postdisaster period (National Institutes of Health, n.d.). Research, particularly by those from outside the affected area who did not experience the disaster firsthand, can place perceived or actual burdens on individual respondents, communities, or systems during disaster response and recovery (Korteweg, van Bokhoven, Yzermans, & Grievink, 2010; Laska & Peterson, 2011).

For these and other reasons, disaster epidemiology has historically been somewhat marginalized from the broader discipline of epidemiology. However, the role of epidemiologists in responding to disasters has expanded dramatically in the last two decades. Rapid Needs Assessment (RNA) methods, adapted from the World Health Organization's Expanded Program on Immunization (EPI) method of estimating immunization coverage, began to be implemented regularly after humanitarian emergencies, beginning with the famines in Somalia (Boss, Toole, & Yip, 1994), and after disasters, beginning with Hurricane Andrew (CDC, 1992; Hlady et al., 1994; Malilay, Flanders, & Brogan, 1996). Emergency department surveillance systems were implemented to capture illness, injury, and mortality data to quantify the health impacts of disasters such as floods in Louisiana (Ogden, Gibbs-Scharf, Kohn, & Malilay, 2001) and Hurricane Floyd in North Carolina (CDC, 2000). Other types of epidemiologic investigations, such as retrospective and prospective cohort studies, began to be implemented to study the long-term effects of disasters such as the terrorist attacks of September 11, 2001 (Savitz et al., 2008), the Indian Ocean Tsunami (Nishikiori et al., 2006), and the Deepwater Horizon oil spill (Stewart et al., 2011). The systematic use of the term "disaster epidemiology" since the 1990s has helped to establish the discipline as a formal subset of epidemiology and encourage its ongoing development (Malilay et al., 2014).

Disasters continue to be a major cause of morbidity and mortality. In spite of large efforts to reduce the impacts and costs of natural disasters, in the United States, average annual federal expenditures to fund rebuilding from catastrophic and chronic losses have been rising faster than either population or gross domestic product (GDP) (Gall, Borden, Emrich, & Cutter, 2011). Globally, the number of people at risk continues to grow along with the populations of megacities located in vulnerable coastal areas, as does the cost of disasters relative to real global GDP (Bouwer, Crompton, Faust, Höppe, & Pielke, 2007). These trends will likely accelerate along with the destructive potential of natural disasters due to climate change and sea-level rise. The following sections present a review of the development in the field of disaster epidemiology and provide examples of disaster epidemiology investigations.

1960s–1980s

Rapid Needs Assessments

Postdisaster RNAs are an important way to mitigate adverse health effects of a disaster among a population. The RNA cluster sampling methods, initially developed by the World Health Organization's EPI in the 1970s, were initially used to obtain data about vaccine coverage and ensure availability of vaccines to all children globally by 1990 (Lemeshow & Robinson, 1985). Since data on immunization coverage and the burden of vaccine-preventable diseases (e.g., tetanus, diphtheria, measles, whooping cough, and polio) were not available, cluster sampling methods were utilized to collect rapid data on vaccination coverage. The data gathered from these initial assessments helped to identify gaps in vaccination coverage and provide data to support the implementation of new programs to address them (Table 1.1).

In the 1980s, the RNA cluster sampling method was used to collect information about breastfeeding and child nutrition to supplement available vital statistics and hospital records

TABLE 1.1 Vaccine Coverage Rates by WHO Region, Development Status, and Income Status, 1980

	Vaccine						
	BCG	DTP1	DTP3	MCV1	PAB	POL3	RCV1
WHO REGIONS							
African	9	8	5	6	2	6	0
American	53	68	50	51	3	67	20
Eastern Mediterranean	18	36	18	15	1	20	0
European	18	73	66	59	0	75	4
Southeast Asian	12	22	7	0	16	3	0
Western Pacific	6	12	8	5	6	5	0
DEVELOPMENT STATUS							
Developed economy	35	67	60	51		59	30
Developing	16	25	12	8	10	15	0
Economy in transition	4	93	90	90	0	90	0
Least developed	10	11	5	6	3	5	0
INCOME STATUS							
High income	38	66	57	49	18	55	26
Low income	16	15	9	10	3	10	0
Middle income	14	23	11	7	9	13	0
NA	3	93	90	90		90	0

BCG, bacille Calmette-Guérin (vaccine against tuberculosis); DTP1, first dose of diphtheria and tetanus toxoid with pertussis vaccine; DTP3, third dose of diphtheria and tetanus toxoid with pertussis vaccine; HepB3, third dose of hepatitis B vaccine; Hib3, third dose of Haemophilus influenza type B vaccine; MCV, measles-containing vaccine; PAB, protection at birth against tetanus; Pol3, third dose of polio vaccine.

WHO/UNICEF estimates of immunization coverage 1980.

(Frerichs & Tar, 1988a). Researchers also used cluster sampling methods to conduct a survey of 396 children in rural Myanmar, collecting data on the proportion of children immunized against diphtheria, pertussis, and tetanus (DPT) polio (OPV), and tuberculosis (BCG) and the ages of children when mothers stopped breastfeeding and when children were first fed protein-rich foods (Table 1.2) (Frerichs & Tar, 1988b). Data were collected on a portable computer and analyzed shortly after interviews were completed; meaning that the time between data collection and the delivery of a report to the Ministry of Health was only eight days (Frerichs & Tar, 1988b).

Public Health Surveillance and Tracking Systems

During the 1960s, most countries had not developed a sufficient public health infrastructure to support regular public health surveillance activities. Systems that did exist focused on

TABLE 1.2 Dietary Intake Among Children in Rural Burma by Age, 1987

	Age in Years		
	0 to 1	1 to 2	2 to 3
Breast milk only	115	18	2
Breast milk and solids ^a	31	89	44
Solids ^a only	2	17	72
Neither	2	0	4

^aSolids include eggs, fish, or meat.

Adapted from Frerichs, R. R., & Tar, K. T. (1988a). Breastfeeding, dietary intake and weight-for-age of children in rural Burma. *Asia Pacific Journal of Public Health*, 2, 16–21.

communicable diseases such as malaria, influenza, yellow fever, dengue, tuberculosis, and cholera; however, little microbiological laboratory capacity was available to support these surveillance programs (Raska, 1966). Even in low resource settings, the need for postdisaster epidemiologic surveillance was made clear after a major earthquake killed 23,000 and injured 77,000 in Guatemala in February, 1976. The Ministry of Health's surveillance network was severely affected by the destruction of health facilities and the loss of communication and transportation infrastructure (Spencer et al., 1977). The lack of public health surveillance data was having a major impact on decisions related to opening field hospitals, conducting vaccination campaigns, and controlling rumors of epidemics (Spencer et al., 1977). Even with limited capacity, a surveillance system was established to collect data on cases of selected diseases, the number of available hospital beds, the availability of medications, and potential outbreaks.

Following a major winter storm that impacted the Northeastern United States in February, 1978, surveillance of emergency rooms and town clerks was established to track morbidity and mortality related to the storm (Glass et al., 1979). The surveillance system allowed public health officials to provide evidence that disease outbreaks and environmental contamination events were not occurring, and therefore quell widely circulating rumors.

Epidemiology Investigations and Studies

During this time period, epidemiological investigations and studies relied heavily on surveys implemented using convenience, simple random, or cluster sampling. For example, after a major cyclone struck Bangladesh in November, 1970, Sommer and Mosley (1972) used cluster sampling to conduct an assessment of cyclone-related morbidity, nutritional status, housing quality, and access to drinking water and latrines over a period of several months. Some epidemiologic studies were also implemented to address the potential long-term impacts of disasters on health. For example, five years after a major flooding disaster associated with Hurricane Agnes (Fig. 1.1), factors such as property loss, financial difficulties, use of alcohol, and perceived distress during the recovery period were associated with continued high blood pressure, somatization, and anxiety among residents of an affected town in Pennsylvania (Logue, Hansen, and Hansen 1980).



FIGURE 1.1 Hurricane Agnes associated flooding in Farmville, Virginia. Photo Credit: No. 72-893, Virginia Governor's Negative Collection, Courtesy of the Library of Virginia.

Beyond natural disasters, in a review of industrial disasters occurring in the 1980s, Bertazzi (1989) outlined a number of epidemiological investigations that were conducted through the use of surveys to ascertain the immediate impacts on the health of affected populations. In addition to postdisaster questionnaires, Bertazzi suggested that follow-up studies should be implemented to better understand longer-term health impacts and that these studies should include the collection and maintenance of biological samples to evaluate the initial extent of exposure as well as changes over time. For example, multiple follow-up studies were conducted by the Bhopal Gas Disaster Research Center and the Indian Council for Medical Research following exposure to methyl isocyanate gas that leaked from a Union Carbide plant in Bhopal, India, in 1984, to enable tracking of long-term mortality and morbidity (Dhara & Dhara, 2002). Multiple cohorts, including cleanup workers and children born to mothers exposed to radiation from the 1986 meltdown of the Chernobyl Nuclear Power Plant in Ukraine, continue to be followed to monitor for health outcomes such as suicide and cancers (Ivanov et al., 2012; Rahu, Rahu, Tekkel, & Bromet, 2006).

1990s

Rapid Needs Assessments

Epidemiological approaches to disaster management and response evolved and grew significantly during the 1990s, with the implementation of better emergency networks for disaster relief and more robust disaster planning (Lillibridge, Noji, & Burkle, 1993). At the same time, increased media attention to disaster relief efforts, as well as the growth of global communication networks put more pressure on disaster response agencies to identify potential public health issues sooner and rapidly implement interventions to mitigate the health consequences of disasters in affected communities. Even with advancing computing technologies, rapid

assessments were still frequently conducted using nonprobability sampling methods. The level of resources required to conduct RNAs remained relatively high, typically requiring outside assistance from various experts to develop assessment instruments, conduct interviews, and analyze data. However, during the 1990s, advances—led by WHO and CDC—were made to demonstrate the use of modified cluster sampling to perform RNAs (Hlady et al., 1994; Malilay et al., 1996; Turner, Magnani, & Shuaib, 1996; WHO, 1999). These advances, as well as the regular use of portable computers to collect and analyze data on-site and immediately postdisaster meant that data-driven disaster relief activities could begin more quickly than traditional methods would have allowed (Lillibridge et al., 1993).

Based on these new protocols, cluster sampling became the gold standard for RNAs globally. For example, following an earthquake in Turkey, an assessment was conducted to determine the needs of disaster-displaced individuals (Daley, Karpati, & Sheik, 2001). Using modified cluster sampling and portable computers to analyze data on-site, the assessment was completed in just 10 days after the earthquake, allowing critical concerns related to shelter, food, and hygiene to be addressed (Daley et al., 2001). Other examples of rapid assessments using cluster sampling included responses to the 1998 floods in Bangladesh (Hossain & Kolsteren, 2003), Hurricane Andrew in South Florida (Hlady et al., 1994), and the First Chechen War between the Russian Federation and the Chechen Republic in 1994–96 (Drysdale, Howarth, Powell, & Healing, 2000).

Public Health Surveillance and Tracking Systems

As disaster management became more standardized through broader implementation of incident management systems in the United States, Australia, New Zealand, Brazil, and elsewhere, the collection of standardized surveillance data became a more important part of tracking the health impacts of disasters. Several reports published in the 1990s demonstrated the effective use of surveillance data in disaster management, when it is vital to fully understand the impact of a disaster on a population's health. For example, following the Rwandan genocide of 1994, mortality and morbidity surveillance systems were established to track the health impacts among Rwandan refugees settled in Zaire (Goma Epidemiology Group, 1995). Ongoing morbidity surveillance was used to observe patterns in disease, assess needs, and effectively implement interventions. For example, the system was used to track cases of diarrheal disease, such as cholera and dysentery, which tended to be highly prevalent among these large refugee populations and could be easily transmissible in small areas. After the 1991–92 famine in Somalia, reviews of data from multiple assessments led researchers to call for the establishment of a surveillance system to track mortality, morbidity, and nutritional status so that data could be used to develop interventions programs and policies (Boss et al., 1994). The standardization of surveillance systems and the sharing of the data collected made it possible for other response groups to utilize similar approaches in other disaster settings.

Epidemiology Investigations and Studies

As highlighted previously, modifications in cluster-sampling approaches made it possible to estimate the total number of people living in the disaster area and the total population in

need of assistance or disaster relief (Malilay et al., 1996). Other researchers modified the cluster sampling approach to conduct national surveys to measure multiple objectives (Turner et al., 1996). In addition, cross-sectional or prevalence studies were also beginning to be used in disaster epidemiology investigations due to their relative efficiency and cost-effectiveness. For example, Chen et al. (2015) conducted face-to-face interviews with victims of the 1998 Hunan, China floods who had been diagnosed with posttraumatic stress disorder (PTSD) to better understand risk factors for chronic PTSD. Although the results from cross-sectional studies cannot be used for causal inference since they cannot establish temporality, they can be used as a basis for developing case-control or cohort studies to identify potential causal pathways.

2000s

Rapid Needs Assessments

After 2000, the focus of RNAs shifted to achieving faster response times, shorter completion times, and the development of standardized tools to systematically collect and analyze data. Since an outside team traveling to reach a disaster-affected area to conduct an RNA can sometimes take more than a week and developing protocols to support the implementation of the assessment can take additional time, disaster-affected and displaced populations may be waiting too long to gain maximum benefit from the assessment findings. For example, during the first several weeks after a disaster, the risk factors and conditions that support the transmission of communicable diseases may begin to increase (Asari, Koido, Nakamura, Yamamoto, & Ohta, 2000). One way of shortening the length of time it takes to begin an assessment is to use geographical informational system (GIS) tools to speed up the processes of sample selection (Waring, Reynolds, D'Souza, & Arafat, 2002). Handheld devices such as tablets, smart phones, and global positioning system devices can be used to collect data electronically, reducing the time needed for data collection (CDC, 2004). Electronic data collection also eliminates double data entry, which can be an important consideration when dealing with the time constraints inherent in conducting assessments during public health emergencies (Horney, Ramsey, Smith, Johnson, & MacDonald, 2011).

Proposals for standardized minimum data sets needed to respond to the public health impacts of disasters were also developed for use by public health authorities and relief agencies (Bradt & Drummond, 2003). Differences in data collection instruments can make it difficult for institutions to combine data from multiple sources or to make policy decisions or develop programs to address the immediate needs of disaster-displaced populations, particularly in the case of major disasters. Standardized assessment tools that could be used to eliminate inconsistencies that can arise when disaster managers adopt different protocols to conduct assessments at different times and locations and in response to different types of disasters were developed. For example, after Hurricane Katrina, numerous agencies and organizations conducted needs assessments of evacuees. Among evacuees relocated to West Virginia after Hurricane Katrina, individual-level data were collected via a rapid assessment developed by the West Virginia Department of Health and Human Resources and CDC. Rapid assessment data were then linked with Red Cross household registration records by name and age to ensure the rapid procurement of services needed to meet the immediate needs of evacuees (Ridenour, Cummings, Sinclair, & Bixler, 2007).

Public Health Surveillance and Tracking Systems

In 2005, the World Health Assembly adopted new International Health Regulations that established a global surveillance system for public health emergencies of international concern (Baker & Fidler, 2006). These new regulations established a list of conditions for which a single case would constitute a public health emergency, including emerging and re-emerging diseases such as severe acute respiratory syndrome (SARS) and new influenza subtypes. In addition, new biosurveillance systems were implemented that integrated electronic medical records and syndromic surveillance from emergency rooms and emergency medical services in new ways that would be useful when monitoring mortality and morbidity resulting from natural disasters (Chughtai, DeVore, Kan, & Streichert, 2016). Syndromic surveillance systems were also adapted and expanded to monitor public health during large events, such as the 2012 London Olympics (Todkill et al., 2016) and the annual Hajj in the Kingdom of Saudi Arabia (Al-Tawfiq, Gautret, Benkouiten, & Memish, 2016).

Epidemiology Investigations and Studies

Recent years have seen increases in the number and intensity of both natural and man-made disasters. Since 1980, hurricanes and tropical storms causing more than \$1 billion in damages have increased from an average of 0.4 per year to more than 1 per year (National Research Council, 2014). The frequency and severity of complex humanitarian emergencies, defined as acute situations in which mortality substantially increases above the population baseline, either directly because of violence, or indirectly due to malnutrition or the transmission of communicable diseases, has also increased since the 1980s and 1990s (Salama, 2004). New areas for epidemiology investigations and studies postdisaster have also emerged, including reproductive (Horney, Williams, Hsia, & Zotti, 2012; Zotti, Williams, Robertson, Horney, & Hsia, 2013) and mental health (Galea, Nandi, & Vlahov, 2005; Neria, Galea, & Norris 2009). Changes in threats—pandemic influenza, suicide bombers—and in health systems and policies—emergency department overcrowding, the Patient Protection and Affordable Care Act—mean that the body of knowledge related to disaster epidemiology can quickly become outdated, requiring the design and implementation of new studies in response to future disasters to continue to build the knowledge base of disaster epidemiology (Noji, 2005).

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