

7 Industrial/Chemical Disasters: Medical Care, Public Health and Epidemiology in the Acute Phase

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7.1 INTRODUCTION

The twentieth century has witnessed the appearance of a whole new series of man-made or technological disasters, resulting from enormously increased industrial growth and chemical utilization. Vast amounts of chemical or potential energy are now focused in highly concentrated areas; unanticipated events can lead to uncontrollable releases with devastating effects (Parrish *et al.*, 1987).

Unintended disasters, and other resultant injuries and health effects, are not simply isolated accidents. Their causes can be studied; the pathways leading to injury, illness, and death can be analysed; the performance of emergency units and medical care systems under extraordinary circumstances can be evaluated. In short, if we are to prevent, control, and manage disasters to the best of our ability, then we must plan and prepare assuming that disasters will occur, and we must scientifically evaluate each disaster to be more knowledgeable and better prepared for the next one.

While the provision of medical care to disaster victims is obviously paramount in the acute phase, from a public health standpoint the following activities must simultaneously be considered (Armenian, 1986):

1. Institute surveillance/information systems to track the extent, severity, distribution, etc., of morbidity and mortality.
2. Anticipate, prevent, or control public health consequences of the disaster (e.g. spread of chemical contaminants in the environment, or appearance of infectious disease epidemics).
3. Assess the utilization and effectiveness of emergency medical and health services.

4. Initiate acute epidemiologic investigations to study risk factors for morbidity and mortality, identify groups at highest risk, evaluate clinical course and natural history of disease, evaluate treatment regimens, identify groups at risk for long-term disease, and study whether the emergency planning apparatus (e.g. warning systems, evacuation plans, provision for acute care) functioned effectively.
5. Develop a solid database so that long-term clinical follow-up and epidemiologic investigations will have full scientific validity. These acute phase activities will proceed over a period lasting from several days to several weeks or months.

7.2 THE DISASTER SETTING: IMPLICATIONS FOR PUBLIC HEALTH, MEDICAL CARE, AND EPIDEMIOLOGIC STUDY

Time constraints place a premium on available plans, data, and record-keeping systems. Emergency preparedness leads to smoother public health response; toxicologic data banks direct appropriate medical care; information systems (e.g. emergency room and hospital records, census and demographic data, environmental exposure data) enable appropriate epidemiologic studies to be performed. To the extent that data and systems are in place and usable at the time of the disaster, they will facilitate appropriate responses.

Although most industrial disasters affect only a limited geographic area, large-scale disasters can broadly affect community services as a consequence of physical and social destruction. Normal operating procedures and personnel may be disrupted, communications systems may be disabled, medical records may go unrecorded or not be retrievable, and population displacement may make health surveys and studies impossible or impractical to perform.

The direct effects of the disaster can be compounded by ineffective management or leadership, legal difficulties (e.g. liability issues may inhibit sharing of needed information), economic or political limitations, psychological stress, or a variety of other factors.

To summarize, the basic methods of the physician, health official, or epidemiologist are not markedly different in disaster as opposed to non-disaster settings; the types of activities are often similar. However, it is enormously difficult to apply well-known or standardized techniques in the context of great destruction, public fear, disruption of usual operating procedures, and broken lines of communication. Planning and preparedness are essential, and carefully crafted procedures and checklists can help; at the same time, prior training in how to respond during emergency situations will aid in handling the difficult circumstances involved. Coordination among medical and public health officials through a central focal point is necessary, as well as early coordination with other governmental authorities involved with medical triage and treatment, relief efforts, relocation, and other societal functions.

7.3 EMERGENCY PREPAREDNESS – DISASTER PLANS

7.3.1 Surveillance of Chemical Hazards

On a local level (e.g. for a community surrounding a single plant) the planning effort may be directed primarily at the inventory of chemicals and the conditions of storage associated with the particular plant. On a broader scale, surveillance activities need to be pursued to evaluate the distribution of chemical plant and transportation releases, the types of chemicals involved, the nature of acute morbidity and mortality associated with the releases, the population groups most affected, etc., (US EPA, 1985; Shaw *et al.*, 1986). In the United States, such databases have most often been established by environmental agencies for their particular purposes, and have often had only limited follow-up information on injuries and acute health effects; greater efforts need to be made to obtain this latter information. The purposes would be to provide an overall estimate of the extent of morbidity and mortality, as well as information on risk factors, and, ultimately approaches to prevention. A recent draft report for the US Environmental Protection Agency (EPA), utilizing several databases in the United States (US EPA, 1985a), has provided stimulating information, such as on the chemicals most often involved in accidental releases, the likely initiating event for the release (e.g. 85% of the total quantity reported released from in-plant events comes from storage vessels), the sources of in-transit events (55% involved trucks), and the chemicals most often related to mortality (chlorine was associated with 9.6% of the events resulting in deaths or injuries). The State of California has undertaken a similar review of hazardous material spills related to transportation accidents (Shaw *et al.*, 1986).

Although these events are relatively minor compared to Bhopal, surveillance mechanisms for large disasters also need to be instituted. Where are the plants with large storage capacity of toxic chemicals? With highly volatile toxicants? Older facilities? Adjacent to population centres? Surveillance systems like these would alert public health and medical authorities to potential hazards and focus appropriate concern on developing adequate prevention activities and contingency plans (Baxter, 1986).

7.3.2 Emergency Preparedness

Because so many government agencies, individuals, voluntary organizations, medical centres, etc., are necessarily involved in emergency response activities, an organizational structure for coordinating these activities is essential. A designated unit or agency to lead this effort should be in place throughout, i.e. during planning, emergency response, and post-response evaluation. In the United States, the Federal Emergency Management Agency (FEMA) has the

mandate for this role, and coordinates a wide variety of disaster responses. It is important to evaluate disaster response activities for the quality of leadership, effectiveness of coordination, and success of response activities.

7.3.3 Disaster Plans

In recent years greater emphasis has been placed on the development of detailed disaster plans concerning major hazards and involving all of the agencies potentially affected. A number of detailed outlines have been prepared and may serve as guidance for such plans (US EPA, 1985b; Foster, 1980; Powers *et al.*, 1981). One aspect which needs to be constantly borne in mind is how quickly such plans become outdated without frequent attention to needed revisions caused by administrative, personnel, legal, and other changes. In addition to the theoretical aspects of such plans, some very pragmatic features must be thoroughly delineated, such as identifying the sources of personnel and funding for carrying out all the features of the plan. An important part of the acute response activities should be to gauge the effectiveness and limitations of available plans (see below). Simulated disaster exercises should also be used to test the quality of disaster plans.

7.3.4 Warning Systems

The lack of an effective warning system at Bhopal was notable. Even when present, warning systems may not function well during the particular event. Several recent studies of disaster events by the Centres for Disease Control (CDC) have documented this problem.

Tornado disaster – Pennsylvania, 1985

The warning message was transmitted over radio and television at approximately 4.30 p.m., a time when many people were not tuned in, and consequently were not warned. Confusion as to the meaning of the warning alert also diminished appropriate responses.

Institute, West Virginia, 1985

A community survey undertaken approximately 2 weeks after a chemical release leading to the hospitalization of dozens of individuals showed that approximately 95% of individuals living in the most heavily affected area did not hear the warning siren.

7.3.5 Evacuation Procedures

Could Harrisburg, Pennsylvania, have been evacuated in time if an explosion

had occurred at Three Mile Island? What are the lessons of Chernobyl? Many impediments exist to effective evacuation. As with warning systems, evaluations during the post-disaster phase can provide important feedback about what does and does not work. In summary, all phases of disaster plans and emergency preparedness need to be reviewed and operationally evaluated to determine effectiveness and potential for improvement.

7.3.6 Risk Factors for Exposure and Health Effects

Studying victims of disasters can often identify preventable risk factors amenable to modification in subsequent situations. Again, while not the highest priority in the acute post-disaster phase, greater validity obtains if questionnaire information is obtained early enough to prevent recall or other forms of bias. Several examples follow from natural disaster phenomena:

1. Case-control studies in post-tornado disasters have identified individuals attempting to escape by car, living in a mobile home, and not having heard the warning alert as risk factors (Glass *et al.*, 1980); all of these can be at least partially corrected in preparing for future tornadoes.
2. A case-control study of heat-stroke victims during the 1980 US heat wave showed that the wide dissemination of electric fans by health departments was not protective, whereas as little as 1/2 hour a day in an air-conditioned environment largely reduced the risk of heat stroke (Kilbourne *et al.*, 1982). As a result, public health practice dramatically shifted.
3. The risk of developing acute bronchial airways disease after the Mount St Helens eruption was essentially limited to individuals with pre-existing respiratory disease; others rarely required hospitalization or emergency room treatment (Baxter *et al.*, 1982). This facilitates planning for future ashfall eruptions.

In a similar manner, studies to be conducted following chemical disasters will undoubtedly identify vulnerable groups and patterns of behaviour and subsequent exposure which will affect medical care and public health practice. At Bhopal, studies might yield information on risk factors such as age, pre-existing respiratory disease, smoking history, and occupational history in relation to the development of pulmonary disease after exposure to the respiratory irritant MIC. Such information might be of value in targeting resources towards highly susceptible groups in future episodes.

7.4 MEDICAL CARE

The battlefield, unfortunately, provided many of the early lessons related to triage and medical care in a disaster setting. The lessons have been incorporated in an ever-broadening base into the civilian provision of emergency

medical services and in planning for civil defence, toxic chemical, and natural hazard emergencies (Beinin, 1985; California Office of Emergency Services, 1983; Health and Safety Executive, 1985; US FEMA, 1984). The particular aspects of greatest importance for the SGOMSEC 6 meeting related to the special needs for handling toxic chemical disasters.

7.4.1 Toxicology Databases

As noted elsewhere, toxicology data banks and poison control centres are essential for providing appropriate treatment. Information must be available at very short notice. The Appendix in Part A of this volume describes means for locating regional poison control centres. In addition, environmental and industrial experts are critically necessary to evaluate the industrial setting, the mechanism of chemical release, the environmental transport and fate of the chemicals released, the route of exposure, etc. This is not simply an exercise in looking up the medical effects of chemical 'X'. One must be aware of all the environmental subtleties which may lead to formation of hazardous chemical by-products or could modify the exposure pathways of chemicals released.

7.4.2 Environmental Exposure Data and Body Burden Measurements

Environmental data may often reliably predict the expected health effects. This is not always the case, and, as happened at Bhopal, the chemical(s) may dissipate before measuring instruments and data can be obtained.

Body burden measurements of chemicals may be possible, but often are not. Chemicals will fall into a number of categories:

1. Those which are metabolized rapidly or are so transiently present in the body that body burden measurements cannot be obtained in time (e.g. certain volatile organic compounds).
2. Those in which a body burden measurement reflects recent (acute) exposure (e.g. urinary arsenic).
3. Those in which a body burden measurement mostly reflects long-term cumulative exposure (e.g. serum PCB), where prior exposures must be considered in interpretation.
4. Those where significant body burden measurements are only available from relatively inaccessible tissues (e.g. selected organochlorine residues from adipose tissue).

Further, many of these tests are not performed routinely in medical care facilities, or are only available from specialized research laboratories. Disaster plans need to indicate the potential chemicals of concern so that appropriate tests can be made available, if needed. For example, at Three Mile Island, special provision had to be made for whole body radiation counters to look at internal uptake of radionuclides.

7.4.3 Medical Treatment Protocols

When considering toxic chemical-specific disaster plans, attention must be focused on the relevant diagnostic tests, treatment protocols, antidotes, medications, equipment, and specialized expertise necessary for the specific chemical(s) involved. Disaster plans need to specify how these resources would be available and used in the acute post-disaster setting. Ready access to specialists with appropriate clinical expertise needs to be identified.

Provision of acute medical care through the emergency medical services system is discussed in Chapter 13. It must be stressed, however, that in addition to the structure, organization, and manpower requirements for medical teams, plans must be carefully crafted for the toxicologic and chemical- and disease-related information systems that will direct the medical care systems. Rapid and accurate toxicologic data for chemical hazards, antidotes for anticipated chemicals of concern, treatment protocols that are appropriate to emergency situations and that are readily available to local physicians, and means of disseminating this information, prior to and during the emergency, are all essential. In addition, physicians will require guidance concerning any necessary or specialized diagnostic tests, clinical examination, or biochemical investigations.

7.4.4 Clinical Investigations

For many chemicals, the acute post-disaster setting may be the first large-scale opportunity to study the effects of the chemical in human beings (e.g. MIC at Bhopal). Pre-disaster planning may identify areas of necessary investigations; in any event, despite the chaos, valid scientific protocols must be utilized to prevent hastily drawn and wrong conclusions. There is a strong, natural tendency in all rapidly evolving emergency situations for individuals (physicians, technicians, etc.) to draw rapid conclusions from limited but immediately and often dramatically perceived personal experiences. It is necessary for public health authorities to be credible by openly and quickly evaluating hypotheses and suggestions in what is often a truly unique situation. At the same time, rigorous attention to scientific methodology, potential biases, data limitations, and other pitfalls in hastily arranged studies must be fully explored.

7.4.5 Initiation of Medical Follow-Up Programmes

In many settings it is highly desirable to link the providers of acute and long-term medical care with the epidemiologists establishing and conducting either short- or long-term studies. In this way, large amounts of data can be effectively collected and utilized. Often, broader individual and societal concerns must also be addressed in this context. For example, following the Toxic

Oil Syndrome epidemic in Spain (1981), a separate agency was established by the Spanish Government, called the National Plan for Toxic Oil Syndrome, to address provision for medical care, epidemiologic investigations, welfare benefits, compensation, and rehabilitative programmes for the more than 20 000 affected individuals. The need for this wide variety of services will be dramatically influenced by the prevailing circumstances at the time of the emergency. Poor nutrition will affect medical care and long-term benefits as well as confound biochemical studies. Limited occupational opportunities for survivors similarly affect medical care, benefits, rehabilitation, and a variety of programmes. At the same time, prior exposures to hazardous jobs, environmental pollution, and illnesses related to poverty, crowding, and socio-economic factors must be considered in the design of valid epidemiologic studies.

Linked to this complex of medical care, socio-economic, and epidemiologic factors, are legal/political issues. In recent years, large-scale lawsuits have in some instances heavily influenced the possibilities available, e.g. litigants will carefully scrutinize proposed epidemiological studies from the viewpoint of their likely impact on courtroom proceedings. Similarly, government agencies may fall prey to political considerations when devising systems for provision of long-term care and benefits. Obviously, public health authorities must consider these factors during all phases of emergency response activities.

7.5 ASSESSMENT OF ACUTE HEALTH IMPACT – EPIDEMIOLOGY/SURVEILLANCE

Surveillance systems must be established early to provide data on the incidence, distribution, location, type, and severity of disease-related health effects. Partially, this may be of benefit in allocating medical care resources; partially this is necessary for estimating the need for other services. Accurate denominator data on populations at risk, and accurate numerator data on numbers of individuals with identifiable health effects will enhance all clinical and epidemiologic studies. For example, accurate case ascertainment for a particular health effect will prevent selection bias from affecting the results of clinical follow-up studies.

Much of what can be done in the post-disaster setting depends on the rapid, systematic collection of routine and non-routine data in an incredibly difficult epidemiologic setting. Factors which affect the ability to collect epidemiologic data include the training, expertise, and availability of personnel (such as environmental epidemiologists); the degree of disruption of routine procedures, societal functions, and data acquisition methods as outlined earlier; the extent to which data can be rapidly collected, collated, analysed (or computerized); the nature, extent, and quality of existing records management systems; etc.

Epidemiologic investigations in the acute phase will vary from disaster to disaster. Such studies will generally be oriented towards the following:

1. Detailed description or overview of the public health impact of the disaster.
2. Natural history of the acute health effects, illnesses, or causes of mortality.
3. Analytic studies to relate exposure and health effects, or to identify risk factors and confounders for the development of disease.
4. Clinical investigations looking at effects of diagnostic and treatment approaches on the health effects involved.
5. Population-based studies to identify individuals at greatest risk for long-term health effects.
6. Studies of the psycho-social impact of the disaster.

7.6 INITIATION OF LONG-TERM STUDIES

Long-term studies need to be initiated early in the post-disaster setting. Because of communal disruption and migration of affected populations, it is important to consider how populations to be studied long term will be identified, registered, and tracked. With the passage of time, it may be impossible to re-create exposed cohorts or to find individuals who should be included in studies. Studies will inevitably be smaller, or more importantly, seriously affected by bias. Therefore, in several recent disasters, rosters of exposed individuals or actual censuses of exposed populations have been undertaken soon after the disaster (within weeks or months). The information collected focuses on identifying information, means by which individuals can be found at a later date (e.g. name and address of employer, names of multiple friends and/or relatives who will likely know the person's whereabouts at any future date, social security or other identifier numbers, etc.), and exposure-related information which might be affected by the passage of time (to prevent recall bias). Examples include:

1. After the Three Mile Island reactor episode, a complete census, with ample identifying and locating information, was conducted of all residents living within a 5-mile radius of the Three Mile Island nuclear reactor; thus, detailed and scientifically sound epidemiologic evaluations can be conducted at any time, if indicated.
2. After the contamination of Times Beach with TCDD was noted, a central roster of exposed individuals, including detailed information on potential activity patterns affecting exposure, was established, with the idea that this roster could be turned into a long-term registry, if indicated. The roster has since been used for various study purposes (e.g. to identify individuals willing to undertake adipose tissue biopsies for TCDD determination).

7.7 CONCLUSION

The acute post-disaster phase is necessarily focused primarily on provision of medical care to the injured and ill. Nevertheless, there is a broad range of public-health-related activities and epidemiologic studies that need to be undertaken in this acute phase. This chapter reviews the spectrum of activities and studies, particularly as they relate to the toxic chemical aspects rather than to the general nature of the disaster.

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