3 Health Assessment and Medical Response

3.1 INTRODUCTION

The human significance of a chemical disaster is measured by the number of people exposed to toxic levels of the substance and the health outcomes at the various levels of exposure. The health effects are measured in short-term (acute) illness, mid-term recovery and rehabilitation or disability, and longer term (chronic) disorders or risk of incidence of latent disease (e.g. cancer). The biologic response to chemical exposure is determined by the toxic properties of the chemical, the dose at which the chemical is received in active form, and the biologic susceptibility of the host. Chemicals vary in their human toxicity according to the presence of biologically active sites on the molecule that allow for reaction with protein, nucleic acid, lipid, or other moieties of the host cell.

Adequate understanding of the health threat of exposure requires qualitative knowledge of the chemical properties of the agent and quantitative information on the ambient concentrations of the chemical at the specific site of exposure, factors that influence the intake and internal conversion to active forms of the chemical, the likely biologic effects, the quantitative relationship between dose and type of response, and the size, composition and distribution of the population affected. All these factors require careful and rapid assessment at the onset of an emergency and by recurrent re-evaluation during the management of the disaster to estimate the risk to health as the event unfolds and to guide effective emergency and long-term health system responses.

This chapter begins with a consideration of this assessment of risk from chemical exposures, addresses the need to plan in advance for such events by securing ready access to toxicological information on chemicals present in large quantities in the community, then describes the essential elements of the immediate and long-term responses in the unlikely event of an incident. Modelling techniques that incorporate the amount of chemical released, its rate of release, and prevailing meteorological conditions can provide data on...
the spread of toxic chemicals in various physical states, thus defining zones of concern for populations at risk. Such models can provide data at the time of the disaster, but more importantly can provide predictive data required for the development of emergency response procedures for individual chemical works. The integration of models, rapid medical diagnosis, local monitoring networks, as well as biological monitoring will provide the data needed for the acute phase of the disaster, and provide the information needed to develop long-term strategies.

3.2 TOXICOLOGY AND RISK ASSESSMENT

3.2.1 Exposure Assessment of the Target Population

Once a hazardous exposure is recognized, a quantitative assessment of the population at risk may be calculated from estimates of the concentration gradient of the chemical from the source through the community, the size of the population in the gradient, and special factors that may influence local concentration of the agent, such as wind direction, temperature inversion, geographical features of hills, valleys, streams, lakes, etc., and physical barriers provided by buildings and use of personal protective devices (e.g. masks, wet cloths, clothing, etc.).

Once released into the environment, a potential exists for human exposure to the chemical. To assist in medical management and epidemiological follow-up, it is imperative to have information on the ambient concentration of the chemical, the period of exposure, and the amount of substance reaching critical sites in the body (the biologically effective dose). Physical protection, such as protective equipment known to be effective in the occupational setting, can be a deterrent to exposure.

Exposure can be determined using direct determination of the chemical(s) in the environment, analysing chemical content of fluids (urine, blood, etc.), clinical observation after exposures, and modelling of chemical dispersal. It is possible to measure the exposure concentration by direct monitoring of the immediate ambient environment. However, because accidents are rapid, unanticipated events, chemical monitors are seldom in place to make this an effective means for obtaining exposure levels. On a practical level, it is more meaningful to obtain an estimate of the dose reaching the organs or tissues through monitoring of biological samples. This is important because the concentration of material to which human beings are exposed may not necessarily be representative of the dose delivered to the target site. (See Section 3.2.2.)

Exposure to a chemical is dependent upon the location of the accident, the proximity of population groups, and other factors. Populations potentially vulnerable to exposure can be broadly segregated by distance from the site of
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the accident. The closest population is likely to be occupational workers (labourers, technicians) and other plant personnel such as administrative, engineering, ancillary, research and development, and transportation staff, firefighters, and others who respond to deal with the accident. The major non-occupational population is characterized by healthy adults and more susceptible groups including children, pregnant women, those with a predisposition for disease, and the aged. The population can be stratified according to proximity to the accident: those in close proximity to the industrial units would be in an intense exposure zone; those at a greater distance in the peripheral zone.

A general descriptive pattern of exposed populations should be promptly categorized and enumerated, and related to the distribution of the agent in the community so that a quantitative estimate of total and distributional exposure can be formulated. Exposure assessment will assist in determining the likely distribution and severity of health effects in the community and thus the allocation of health resources.

3.2.2 Dose to Target Tissue

The dose reaching target sites is modulated by rates of absorption, distribution, metabolism, and excretion, and the nature of the major site of toxicity. In addition, other factors, such as age, sex, immunologic state, physical activity, and individual susceptibility will affect the biological dose. The biologically effective dose is concentration- and time-dependent, both with regard to the external concentration, the duration of exposure, the rate of absorption through biological barriers, and the rate of excretion. With regard to the duration of exposure, some substances have an intensity and variety of toxic effect with increasing time of exposure; others have no increase in effect with increasing time of exposure. Duration of toxic exposure relates to biologic clearance capabilities ($t^{1/2}$), as well as to time of external exposure.

Biological monitoring can be used to provide an approximation of dose and potential health effect, but for only a limited number of substances where sufficient experimental and modelling information is available (Piotrowski, 1985; Lauwerys, to be published). A possibility exists to roughly approximate the dose received using biomonitoring data in two ways: through comparisons with other empirical data where biological consequences are known; or through toxicokinetic modelling. The uncertainty factor of such calculation should always be kept in mind, especially in cases where combined exposure to several chemicals is likely to have occurred.

Biological monitoring will be more valuable in the follow-up to a chemical accident than during the initial phases where rapid decisions must be reached on the need for medical treatment and/or evacuation. Such techniques are usually of more value in assessing individual exposures than in exposure of
populations. Rapid disappearance of substances from the body often precludes the use of biomonitoring techniques.

Chemical disasters involve massive exposures to toxic chemicals, and may involve more than one agent. The acute effects are often the result of toxicity to more than one target organ, so that the long-term outcome is complex and uncertain. New innovative, and highly sensitive techniques to measure biologic alterations of long-term significance, such as DNA adducts and protein adducts, are on the horizon or are under development. Some of these techniques can provide data long after exposure. While these techniques do not have broad-scale application as yet, their development and use should be encouraged.

3.2.3 Biological Response

The main routes of entry of chemicals into the body are eyes, respiratory system, integument and gastrointestinal tract. Once in systemic circulation, regardless of the route of entry, a variety of systemic effects can occur, including pulmonary, cardiovascular, neuromuscular, hepatic, renal, hematologic, reproductive, metabolic, and hormonal changes. The nature of the toxic or adverse effect is influenced by a variety of factors, including physicochemical characteristics of the substance(s), atmospheric transport, dispersion, chemical reactivity and transformation in the environment, the route and extent of exposure, and biotransformation in the host.

Many physiologic and environmental factors can modify the human response from exposure to chemicals, including age, sex, reproductive status, genetic make-up, nutritional status, pre-existing disease states, and status of the immune system. For a given exposure, children, pregnant women, the aged and sick may be more susceptible than healthy adults. Of special concern in pregnant women is the potential damage to the foetus. However, in some cases, pregnant women have themselves been shown to be more prone to the toxic effects of chemicals than non-pregnant women (Miller et al., 1987).

Genetic make-up may determine the biotransformation of toxic chemicals, as well as the susceptibility to its action at the molecular level (Kalow, 1983). Also, nutritional status is known to alter the biotransformation and disposition of chemicals. Such factors as malnutrition, undernourishment, and vitamin deficiencies have been shown to play such a role.

The pathological and physiological states of the individual may play major roles in determining the biological response after exposure to a chemical. Pre-existing conditions such as respiratory diseases (including allergies), liver and kidney diseases, and skin disorders can modify the toxic response. The immune system plays a major role in determining the adverse effects caused by exposure to chemicals. Thus, an immune deficiency or enhancement can lead to a more severe response from similar chemical exposures in different populations.
3.2.4 Dose-Response Relationships

The dose–response relationship is usually represented graphically by a sigmoidal curve approaching zero and 100% response at the low and high dose ranges, respectively. Such a function may be linearized in a variety of ways, allowing for extrapolation to the low probability range, where the exposure is relatively low (Vouk et al., 1985; Dolezal and Pokorny, this volume, Chapter 6). Reasoning in terms of dose–response relationships is essential to provide general guidance in the assessment of risk of all kinds of exposures. Extensive toxicological data are recorded in centralized computerized databases which require improved access for maximum effectiveness. However, there are still numerous individual chemicals where detailed data on such relationships are lacking.

Another consequence when predicting the outcome of an accidental release is the shape of the ‘susceptibility curve’. Depending on the shape of the dose–response curve, or the width of the ‘susceptibility curve’, there is a greater or smaller likelihood of a toxic impact at doses much lower than the median toxic dose. Unfortunately, the use of this concept in characterizing the toxicity of the chemical has been limited to date.

From the above considerations, it follows that a continuing effort should be encouraged to enlarge toxicological databases with data derived by sound scientific practices, especially for those chemicals that are likely to cause accidents. This line of research is also important to the understanding of the health impacts of accident releases of toxic chemicals.

3.3 IMMEDIATE RESPONSE TO A CHEMICAL ACCIDENT

In cases of chemical accidents, it is self-evident that the main aim for all respondents is to prevent and reduce the effects of the accident. In human beings, this means that every effort should be made to minimize illness and fatalities. The society must plan for adequate systems in this respect. Immediate medical responses to chemical disasters draw on the regular emergency medical services which should be integrated with hospital-based medical services, and with emergency services such as fire, police, etc. However, the magnitude of the disaster requires rapid expansion of the scope of response and strengthened coordination, direction, and control of the response teams. In addition, existing disaster plans must be extended to include chemical disasters and the response teams trained accordingly. The main responsibility of public health authorities in this context is to provide public health guidelines and to coordinate these activities, especially with environmental and emergency agencies in the community.

A major immediate need in chemical disasters is the need for chemical and toxicological information. Responsibility must be assigned to improve available toxicological information on industrial chemicals and to make this
information generally and directly accessible in the acute situation. It is of fundamental importance that efforts are made to guarantee that all possible experience from every accident, minor or major, will be recorded. Preparation for follow-up studies and research programmes must always be included in the planning for chemical accidents.

All planning and other activities must include not only the acute situation but also the pre-event and post-event periods.

### 3.3.1 Emergency Medical Response

Emergency Medical Service (EMS) must play a very vital role in minimizing health injury to the affected community during any chemical disaster. The main points are how quickly and effectively the EMS can be mobilized; the sooner it is done, the better the results will be. To achieve this, communities obviously need adequate planning well in advance of the emergency. The medical emergency response plan should be part of a broader disaster plan prepared by competent personnel and readily accessible at the time of accident for immediate implementation. (See Chapter 5, Disaster Emergency Planning.)

### Operations and Activities at the Time of Accident

On notification of a chemical disaster, the responsible Emergency Medical Service authority should initiate a sequence of actions:

1. Put into action the alarm or warning system to activate the emergency medical procedures.
2. Institute a triage system appropriate to the accident and the medical situation.
3. Provide immediate relief to seriously ill people in the form of first-aid treatment, resuscitation and shifting to hospital.
4. Establish emergency relief centres for treatment, management and registration of affected or exposed populations.
5. Appropriately identify the dead (including certification if possible), and initiate disposition of the dead.
6. Collect biological samples from patients and the exposed population, and environmental and legal specimens, with a view to aiding proper diagnosis, understanding of pathology, development of an antidote, and administering appropriate therapy in the period immediately following the emergency. This information will be utilized for research investigations, compensation and legal action. Additionally, data collected from environmental and animal exposures may shed light on pathophysiology and diagnosis. (See Chapter 4).
7. Provide accurate information to public health authorities and the public on
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the extent of medical effects to prevent unfounded rumours and misunderstanding. All efforts should be made to prevent panic and inappropriate response.

Transport

Emergency vehicles available to the community, such as ambulances, helicopters, and other vehicles for evacuation of patients and for medical transport, must be available. These vehicles should be properly equipped and ready to use as soon as the emergency occurs.

Hospital Services

1. An adequate number of doctors, nurses, other paramedical and supporting staff trained in disaster management must be immediately notified. It may be necessary to shift adequate staff from other regions, hospitals, etc. Anticipated staff needed from outside the local areas should be notified with as much lead time as possible.

2. A sufficient number of hospital beds must be made available to treat seriously affected people, utilizing the disaster plan to organize and enlarge the available capacity.

3. Specific antidotes plus medications for symptomatic treatment should be stored in sufficient quantity to meet all contingencies.

4. Life-supporting systems, e.g. oxygen therapy, continuous positive airway pressure breathing systems (CPAP), artificial ventilation, dialysis, blood and fluid transfusion, should be available.

5. Maintain accurate morbidity and mortality data in a register set up specifically for the exposed population.

Emergency Health Centres

Emergency health centres are health care delivery units which are set up at the time of the emergency to partially share the responsibility and relieve the pressure on regular hospitals by treating and managing less severely affected patients not requiring hospitalization. These centres can be temporarily located in suitable and safe places as near as possible to the site of the accident. Their number and capacity will depend upon the magnitude of the accident and the population to be treated. The centres should be manned by people who are trained to provide first aid and outpatient treatment to affected and exposed people. The centres should have the responsibility of maintaining records and registers of affected or exposed people in that accident for future use in follow-up and research. Further reading may be found in contributed papers to this volume: Pokorny, Chapter 6; Kulling, Chapter 9; Falk, Chapter 7; Levine, Chapter 10; and Sriramachari, Chapter 15.
3.3.2 Public Health Responses

This section of the report focuses on public health activities during the actual emergency, and in the immediate post-event (aftermath) of the disaster. The planning activities that prepare a community for disaster response are discussed in Chapter 5, Disaster Emergency Planning.

In this section, we highlight the responsibilities for leadership and coordination by public health authorities to interact closely with environmental and other agencies, and the necessity to develop sound databases on local hazards and chemicals of concern, the types of public health actions that need to be undertaken in a chemical emergency, and the importance of initiating appropriate scientific and research investigations as soon as practicable.

Leadership and Coordination

The health department will be the primary contact with the exposed population and must provide guidance on (a) whether affected populations can stay in the area or should temporarily be evacuated, and (b) what additional measures need to be initiated to prevent further exposure. During the immediate phase of emergency, the activities of public health authorities must include the following:

1. Identify the source(s) of the chemical hazard(s) and verify with environmental units that further releases have been stopped. (Usually control of the release will be performed by occupational and environmental units which may be in separate agencies from the health department.)
2. Verify the distribution of the released chemical(s) in the environment as defined by environmental units and assure that ongoing exposure to affected populations is stopped. (Usually, monitoring of the environment for specific chemicals and modelling of plumes in the environment are performed by environmental units which may be in separate agencies from the health department.)
3. Assure that clinically affected individuals enter into the medical care systems.
4. Evaluate all potential mechanisms by which the released chemical(s) may create public health hazards, for example: Has the chemical contaminated drinking water supplies? Do animal carcasses present an infectious disease hazard? Are adequate food and sanitation available for evacuated populations?
5. Assure that all appropriate activities in the disaster plan have been initiated.
6. Provide feedback on the adequacy of the emergency plans, toxicology data, medical responses, etc.
7. Make decision about whether emergency regulations or systematic investigations need to be instituted to prevent similar episodes elsewhere.
8. Develop an effective transition from the initial emergency response to the long-term activities (Section 3.4).

In the aftermath of a chemical emergency, it is important for the health departments to have available specific medical or toxicological experts who can act and give advice with authority. Such persons can be a source of information for exposed people, the general public emergency personnel, and others. Equally important, such experts can assist the health departments in many ways, such as by helping to initiate research activities.

Information

Clear, correct, credible information must be transmitted rapidly during the emergency situation. The public health authority should coordinate the release of up-to-date information, with every effort made to prevent misinformation and rumours from leading to inappropriate behaviour. In order to alert the public and the emergency personnel, to get essential help, and to transmit information about the achievements of the emergency responders, lines of communication must be clear, effective, and consistent with the local resources and practices. Multiple means of communication may be helpful to disseminate warnings and other information. Back-up systems should be available in case of failure of a primary system of communication. The effectiveness of the intervention greatly depends upon the presence of a task force previously organized and trained to face this type of accident. The need applies to both national and international organizations. The accident might occur in countries which lack some specific experts (e.g. epidemiologists). In this case, the international organizations concerned (WHO, ILO, IPCS, IARC, etc.) are prepared to be asked for assistance both from the point of view of information available from existing data banks and from experts at any level in field studies.

Databases

All relevant toxicological information must be directly available in the acute situation by:

- material safety data sheets;
- direct access to point centres (or equivalent bodies), or computers;
- access to a key person at the chemical plant for detailed information on the toxic substance(s). (At each plant, some responsible person must be available on a 24-hour basis.)

New accident-specific databases must be established through:

- systematic and unbiased registration of people to be included;
- complete lists of individuals for medical surveillance, compensation, and
rehabilitation purposes including personal identifiers that provide enough information to find the person at any appropriate time in the future; short-term toxicity tests to gather data immediately useful in treatment and planning.

Additional data collection from toxicological (or other) resources must be started quickly, especially if available information is sparse or lacking. Further reading may be found in contributed papers to this volume: Falk, Chapter 7; Levine, Chapter 10; Kulling, Chapter 9; and Varadarajan, Chapter 16. See also Appendix to Part A of this volume for additional resource documents.

3.3.3 Investigations and Studies

Every chemical accident, large or small, presents an opportunity for systematic (well-organized) research investigations both from the epidemiological and clinical pathological perspectives. Such investigations yield information that is useful not only for the follow-up of the victims of a disaster, but also for the institution of more specific methods of treatment, and, above all, enlargement of the database for future use. Such research should be well thought out and initiated in a coordinated manner. The essential steps to be taken are outlined in the following paragraphs.

**Systematic Registration**

The dead, sick, and exposed at all levels should be identified and registered in a process to be initiated from the very onset of the disaster or as soon as practicable. This registration must be coordinated and cover the whole population in the affected area. Registers or consensus of dead, sick, or exposed persons are necessary for establishing valid scientific protocols, and also for other purposes such as providing compensation and medical care.

**Clinical Toxicological Studies**

Systematic examination of clinical records and observations of the critically ill (acute and sub-acute victims) of all major or significant chemical disasters should be undertaken according to a generally agreed protocol, on the initiative of the nearest available Emergency Medical Service and local, state, or national health experts who may be mobilized for this purpose. The data collection should include the following:

- complete or comprehensive clinical investigations and recorded data;
- radiological findings wherever and whenever indicated;
- clinicopathological information on the blood and urine or other body tissues;
- additional biochemical tests where indicated.
In addition, care should be taken to collect and store frozen uncontaminated samples, when appropriate, for future investigation (e.g., to identify the incriminating/suspected chemicals, or for other purposes).

**Autopsy Studies**

Wherever possible, clinical post-mortem examinations should be carried out by appropriate forensic pathologists. Care should be taken to preserve adequately sufficient tissue samples for chemical analysis. The provisional anatomical diagnosis (PAD) should be followed by a detailed histopathological confirmation by light (and electron) microscopy of tissues of all the target systems and organs, indicating the relative involvement of the respiratory, cardiac, neurological, hepato-renal, cutaneous, or other systems. Care should be taken to record the occurrence of any pre-existing disease or prevalent conditions such as tuberculosis, anaemia, malnutrition, vitamin deficiencies, or occupational illnesses that occur frequently in the victims' community. An attempt should be made as early as possible to correlate any specific autopsy findings with the chemicals of concern so as to improve the emergency medical care and to institute more specific treatment (e.g., antidotal) schedules in the ill patients.

**Studies of Late or Continuing Organ Damage**

Clinical, biochemical, immunological, chromosomal, electrophysiological, tissue, and other appropriate information of a relevant nature should be assembled through a system of close coordination and liaison between the clinical and laboratory divisions of the emergency hospital care services. Particular attention should be paid to the following sequelae – pulmonary, haematological, cutaneous, liver, kidney, neurological, and reproductive organs among others. Related biochemical and tissue information (when available) should be taken up with the help of light (and electron) microscopy and other appropriate investigative methods. 

Similarly, immunological, cytological, and other specialized investigations should be initiated as soon as sufficient justification becomes apparent. Depending on the magnitude and type of the chemical involved and the specific population at risk, detailed studies related to teratogenicity, mutagenicity, and carcinogenicity may be taken up.

**Epidemiologic Studies**

Epidemiologic studies should be conducted according to specific protocols, to ensure scientifically acceptable study design and statistical validity. Careful attention must be given to the collection of baseline data, or information from
control or comparison groups, to avoid biased conclusions. Because of the difficulties of conducting sound epidemiologic studies in the aftermath of a disaster, experienced epidemiologists are needed, often with the assistance of expert technical consultants. Planning for epidemiologic studies, and the development of study protocols should start as soon as practicable.

Epidemiologic studies are done for a variety of purposes. Descriptive epidemiologic studies will provide an overview of the public health impact of the disaster (e.g. number of fatalities, rates of illness in the population, hospitalization rates). In addition, in the aftermath of a chemical disaster, epidemiologic studies will often focus on the following:

- accurate estimates of chemical exposure in the affected population;
- correlation of environmental and human exposure data;
- relationship of chemical exposure and dose to observed effects (subclinical effects, morbidity and mortality);
- the interactions of a variety of risk factors (such as individual susceptibility, behaviour, socio-economic factors, age, race, sex, occupation, pre-existing disease, occupational exposures, other environmental exposures, use of alcohol, cigarettes, and drugs), with chemical exposure and the development of health effects;
- the evolution or natural history of the disaster-specific, chemically-induced illness;
- the impact of various therapeutic regimens on the progression of the disease;
- the utility and effectiveness of various screening and diagnostic tests;
- the ability of individual tests or specific data to serve as markers to predict accurately the outcome (prognosis) in specific patients;
- the degree of success in implementing the various aspects of the disaster plan (such as the effectiveness of warning systems, evacuation plans, provision of medical care, etc.);
- the psycho-social impact of the disaster.

Successful investigational approaches require close collaboration among clinicians, pathologists, epidemiologists, statisticians, environmental scientists, and relevant field staff. For maximum benefit, results must be presented in a clean and timely fashion. Some epidemiological studies are of a long-term nature, reviewed in later chapters of this book.

Further reading may be found in contributed papers to this volume: Sriramachari, Chapter 15; Falk, Chapter 7; Kulling, Chapter 9; and Krishna Murti, Chapter 8.

### 3.4 LONG-TERM RESPONSES

The detection and evaluation of long-term health effects subsequent to a chemical accident are prerequisites to development of ad hoc remedial action,
to minimize injury to the exposed population, and to quantify biological damage. The information thus generated constitutes a body of knowledge that may be of great value in the prevention and management of further accidents or other types of contamination. In addition, it is essential to ensure that all long-term measures and studies be well planned immediately after the accident. Necessary mid-course corrections and additions can be made periodically.

Events in the very early phase following the accident will determine the course of action. Long-term epidemiologic or medical investigations require systematic and unbiased recording of individuals to be included for study. Because of the population dislocation in any large-scale disaster, this enumeration (census, registry) of the affected or ill population must be done as early as possible after the emergency. Otherwise, many individuals may not be included in follow-up, leading to incomplete or biased investigations. Since this survey to set up the census of exposed or (potentially) affected individuals will be done during an emergency, information collected should be limited to essentials. As long as the individual can be identified and found later on, additional information can be collected at a future date.

The findings of the early investigations, even if they are regarded as preliminary or incomplete, should be made available to those organizing the long-term projects. The long-term projects should be designed to generate information suitable for a quantitative risk analysis.

### 3.4.1 Medical Response

Health Services

Disasters and accidents by definition are sudden in onset and progress rapidly. Medical rehabilitation is a concerted effort of many disciplines and organizations. Post-emergency care may require special attention and documentation.

Quite often, the health personnel are unprepared and unaware of the health consequences of toxic substances. The medical community, which in some situations consists of private (general) practitioners and small dispensaries, is often ignorant of the existing emergency situation. Therefore, the post-emergency care needs to be collected and activated in hospitals/health care centres, etc., and a systematic approach has to be developed to meet the demands for treatment and follow-up. This essentially involves information dissemination to all health personnel. Relevant clinical and toxicological information, guidance, and therapeutic measures must be readily accessible to hospitals and other organizations involved in treating disaster victims. Adequate and proper information must be provided. There is a special requirement to look for unusual symptoms and suggest appropriate investigations to assess both subclinical and overt disease manifestations. The adequacy and
promptness by which the diagnostic and relief measures are undertaken will greatly influence the long-term effect. The post-emergency medical care will, therefore, have to be systematic and prompt and offer effective remedial measures. A major task of the medical personnel in charge of the long-term follow-up of the victims of a chemical accident is to plan appropriate rehabilitation programmes, since they may substantially contribute to the future quality of life of the affected persons.

Post-emergency care of the exposed individuals requires special care and attention which may not be made available at the usual medical health centres. Therefore, it would be advisable to have 'special clinics' in organized medical centres and local hospitals where the exposed individual can have easy and regular consultations depending on the symptomatology. Organization of such clinics will depend on the existing medical infrastructure.

Such 'special clinics', in addition to providing health services, can maintain proper records for future activities. They can develop a solid database so that long-term clinical follow-up and epidemiological investigations can be undertaken. Immediately following the emergency, exposure assessment and health effects have to be clearly documented and preserved. Valuable data can be used to interpret the occurrence, pattern, and time trends on the basis of systematically collected data. The number and size of health centres will depend on the magnitude of the problem and tasks. It is necessary to have a single major health centre to function as a coordinating body.

**Occupational Health Services**

In such emergency situations, it will be advisable to draw upon occupational health services in the community, both those owned by companies located in industrial settings, and those that are operating in the frame of local public health activities that play a relevant role in the post-emergency medical care. The personnel of these services have higher training in clinical toxicology with respect to general practitioners. Furthermore, occupational health facilities generally have medical equipment suitable to conduct rehabilitation programmes. It is thus conceivable in some cases that these resources, manpower, know-how, and instruments can be made available to assist the rehabilitation of affected people. Agreements between the local health authorities and the company management should consider and plan for the operational aspects of this cooperation. The data collection in these centres, particularly with respect to the treatment, must be made available to the hospitals and special clinics which are dealing with exposed victims.

**Role of Voluntary and Community Organizations**

Voluntary health organizations and community health organizations in the
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specified area of the disaster should be approached and provided with accurate information on the accident, toxicity data for carrying out treatment and surveillance of victims. Treatment can be curative and rehabilitative. Necessary format may be supplied to these organizations for the collection of information about the victims. These data will be useful for further research also. These organizations can provide treatment facilities if available, or refer the patients to nearby clinics specially created for treatment of the victims. Special clinics should collect data gathered by the voluntary and community health organizations.

Social and voluntary organizations may help in creating an awareness among the community to have regular medical check-ups to identify chronic processes evolving after acute exposures which can be effectively treated at the special centres or hospitals. It would be advisable to have community surveys properly spaced to identify long-term sequelae. The rate of participation may be enhanced by proper mass media communication and educational programmes.

3.4.2 Public Health Response

The public health action taken in response to a chemical accident, in the long term, includes intervention in several areas.

Regulation

New regulatory action, or a stricter enforcement of pre-existing rules, will ensure a safer handling of chemicals in the affected area.

Monitoring

Programmes of environmental monitoring will be designed and conducted, with the twofold aim of learning about the fate of the chemical in the environment and evaluating the persistence of sources of hazard to health in the affected community.

Surveillance and Long-Term Follow-Up

With respect to the evaluation of the long-term health effects of the accident, major efforts should be devoted to the start of a surveillance programme. The surveillance system has the purpose of assessing the health consequences of the accident and evaluating the curative and rehabilitative measures adopted, including emergency measures. The design of the surveillance systems depends on the characteristics of the chemical agents involved, modes of exposure, the organ systems affected (see Figure 8.3, Krishna Murti, this volume), available information concerning their toxicologic properties, and, most important, the
current state of health care in the area of interest. An effective surveillance system must take into account both the requirements of information and the constraints represented by feasibility aspects.

Several crucial issues related to the identification of the exposed people and the definition of the outcome variables have been discussed in detail (see this volume: Krishna Murti, Chapter 8; Falk, Chapter 7; Silano and Comba, Chapter 14; and Dolezal and Pokorny, Chapter 6). If the assessment of exposure has been performed at the individual level, the results of the surveillance systems will be more specific, while if the assessment is mean exposure at the geographic level, a dilution of the observed effects is likely to take place.

An intensive long-term follow-up inclusive of clinical and laboratory tests can be reasonably performed only for restricted groups at high risk, while a population-based surveillance programme should bear on currently collected information such as mortality figures and hospital admission cards. In some instances, the use of sentinel health events can represent an alternative to the conduct of exhaustive programmes. The duration of the surveillance programme is a function of the target health responses; it is necessary periodically to evaluate the programme and to redefine priorities in the light of resources and new available data, as well as feedback information from ongoing activities.

Technology Transfer

The transfer of technology among countries, and especially the transfer of hazardous chemicals and industrial processes from industrialized to developing nations, requires the adoption of large-scale international cooperation in dealing with the long-term effects of chemical accidents, both with respect to the rehabilitation of victims and the design of a health surveillance system. Chemical disaster management will need inputs from various expert groups and information on various aspects of the chemical agent. A high level of expertise and a comprehensive data bank involving information storage, retrieval, and dissemination system will be required. Thus, depending on the prevailing conditions in a country, adequate measures should be taken to create infrastructure facilities and develop expertise in various areas such as toxicology, epidemiology, and medical and environmental health sciences, and the appropriate technology in the domain of information and telecommunications.

3.4.3 Investigations and Studies

Research activity subsequent to a chemical accident should be prompted by the need for assessing long-term effects in humans of the exposure to the chemi-
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medical(s) concerned. This applies not only to the situations in which little or no information is available on the toxicological potential of the chemical, but also to other compounds for which experimental and human data are available. In view of the rare occurrence of the exposures related to accidents, and also of aspects related to compensation, specific areas for research will have to be identified and investigated using animal model systems or human subjects already exposed.

The nature and extent of research to be undertaken should be directed and evaluated by a scientific advisory committee constituted for the purpose.

Epidemiological Research

1. Potential health effects to be investigated:
   - carcinogenic effects;
   - teratogenic effects;
   - effects on reproduction, fertility, abortion;
   - effects on genome, chromosomal aberrations, gene mutation;
   - effects on the immunological system; modification of the host response which should be investigated both through laboratory tests and recording of morbidity;
   - other chronic effects on other target and non-target systems.

2. Methodological aspects:
The methodological approach can be different depending on the organization of the public health system existing in the country where the accident has occurred. An integrated central system operating in the acute phase permits the follow-up of the individuals and the exposed population. In other circumstances, this population should be defined and identified as soon as possible and a cohort constructed for follow-up through the standard mechanism of tracing. When, as in most cases, this central system does not exist, it is necessary to set up, through a registry, active mechanisms of follow-up. This can include the entire population or an appropriate sample of it depending on the size of the exposed population and on the magnitude of the effect under investigation.

Another important point is whether or not health effects of the compound under investigation are already known. Sufficient information on health effects would in fact allow focus on specific target organs and would facilitate the task particularly in countries with less efficient tracing systems. In this case, monitoring of sentinel events or case-control studies could be an alternative methodological approach.

Follow-up of the individuals, particularly in the situations in which an active follow-up is required, can be facilitated by medical care, rehabilitation and compensation aspects.

The completeness of the registers and the effectiveness of the follow-up are largely dependent on the rapidity of the intervention after the accident. Any
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delay in the definition and identification of the population considered at risk is crucial and will dramatically influence the follow-up and therefore the chance of detecting an effect. This particularly applies to any asymptomatic individuals.

Evaluation of the Intervention

Considering the human and economic resources involved in the research activity, it is recommended that, during the course of the investigation, the effectiveness of the health service responses and the studies undertaken be evaluated. For instance, if several new cases are detected among people who were not identified as members of the exposed population, and thus followed up in time, the reliability of the mechanism set up should be questioned. This control should possibly be performed by an ad hoc group of experts in this field.

Evaluation-oriented research is a valuable tool for the organizations in charge of medical response and public health activities, since it provides figures and data which are needed to allocate effectively the available resources.

Experimental Research

Particularly when little or no information is available on a chemical compound, experimental studies are mandatory in predicting possible effects on human beings. In addition, further information will be derived concerning mechanisms of action, dose–response relationship and treatment.

The experiments undertaken should mimic as far as possible the characteristics of the accidental exposure to the chemical(s). Very useful information can be derived in a very short time from experimental short-term tests such as genotoxicity tests.

3.4.4 Recommendations

Medical Care

1. Adequate training should be provided for all those involved in accident management. Education and training should be appropriate to the particular groups being trained.

2. Medical facilities should be properly managed and be sufficient to take care of all affected (exposed) people, both in hospitals and in the emergency health centres.

3. A high rate of participation of patients in the long-term follow-up programmes should be pursued by:
   - motivation of the affected subjects;
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- education of general practitioners;
- information on the community through the media.

Information Dissemination

1. The accessibility of basic toxicological and chemical safety information should be increased through further development of those international and national agencies willing to share such data with those in need.
2. Further effort should be made to enlarge the toxicological databases on those chemicals most likely to be involved in chemical accidents in the future.
3. Further effort should be made to improve the methodologies of interspecies extrapolation of toxicity data to allow for a more rational use of such information in the assessment of risk to humans.
4. Continued effort should be given to the improvement of tracking the inventories of chemicals likely to be involved in accidents in the future. Special emphasis should be given to the newer methodologies of DNA and protein adducts to allow for reconstruction of the magnitude of exposure long periods after the exposure.
5. There should be provision for exchange of scientific information and data soon after the accident, as well as at appropriate intervals, care being taken to ensure that the interests of the victims are not inadvertently jeopardized. Preferably, such exchange should take place through accredited international scientific bodies or organizations.
6. Among the information transfers that are helpful in the implementation of public health action, special emphasis should be given to:
   - training of health personnel in the various topics related to chemical accidents;
   - dissemination of the relevant information among industrial managers, technical staff and workers;
   - education of the community.

Research Initiatives

1. All significant chemical accidents or disasters should be considered to have a great potential for launching research initiatives for augmenting previous knowledge and generating new information. This would be of immediate relevance to the accident in question and for the future.
2. Coordinated steps should be taken soon after the accident for proper registration of all affected individuals for purposes of medical care, epidemiologic investigations, relief, rehabilitation, and legal compensation.
3. The opportunity provided by an accident for undertaking unique studies in clinical toxicology should be fully utilized. The medical and research
resources should be brought together to carry out immediate, relevant, and necessary investigations and studies. For this purpose, it would be necessary to bring together the local, state, national and international agencies.

4. Appropriate laboratory investigations of survivors, including pathology information and carefully correlated clinicopathological autopsy studies and chemical analysis of tissues, should constitute a major activity after an event. Assurance should be given that the tests are optimal and not redundant. Valuable tissue samples should be preserved in duplicate for any subsequent analysis. The aim of these studies should be enhancement of the specific and antidotal treatment schedules and a better understanding of the decision process.

5. A wide range of community-based epidemiologic studies should be initiated right from the time of registration and for a sufficiently long time to follow up the immediate, delayed and late adverse health effects in the general public and in special high-risk groups. Strong consideration should be given to developing a skilled environmental epidemiology unit to initiate and conduct these studies.

6. Even if emergency and post-emergency situations are not the most suitable settings for the implementation of research programmes, they should be designed and conducted under the supervision of a scientific advisory committee with the allocation of the needed resources. Epidemiologic studies, research aimed at the evaluation of the effectiveness of the adopted measures, and experimental investigations should be promoted.

The scientific advisory body should promote research in the following areas:
- epidemiology;
- clinical toxicology;
- evaluation of antidotes and treatment protocols;
- experimental models;
- evaluation of response systems.

The scientific advisory body provides consulting activity in these domains, and maintains contacts with relevant expertise available both within and outside the country, in the framework of international cooperation.

REFERENCES


