12. Chemical incidents

12.1 Types of chemical incident

A chemical incident has been defined as "an unexpected uncontrolled release of a chemical from its containment". A public-health chemical incident has been defined as "where two or more members of the public are exposed (or threatened to be exposed) to a chemical" (World Health Organization, 1999d). In the majority of cases, this is an acute release, where the exposure dose is rising or is likely to rise rapidly. When the release is chronic, the exposure and dose do not rise quickly and public-health measures do not have to be taken so rapidly, though the public-health concern may emerge suddenly and acutely. This chapter is concerned with acute releases. It is not concerned with incidents involving attacks with chemical weapons.

12.2 The health effects of chemical incidents

Chemical incidents affect people in a number of ways, including:

— the effects of explosion;
— the effects of fire;
— the toxic effects of the chemicals.

12.2.1 Toxic effects of chemicals

Chemicals enter the body through the skin, eyes, lungs or digestive tract. The rate of absorption via these paths is different for different chemicals, and is also affected by the concentration of the chemical in contact with the body (the concentration may change over time), the length of time that the chemical is in contact with the body, the air temperature, humidity and the person's age.

Within the body itself, the effect depends upon the actual toxicity of the chemical and on the biologically effective dose (i.e. the quantity of chemical taken into the target tissue). The way the dose is accumulated in the target tissue can make a difference to its impact. Even if the exposure is short, the peak level might be high enough to cause toxic effects. When the exposure is prolonged and the dose rate low, it may be the total cumulative dose that causes toxicity.

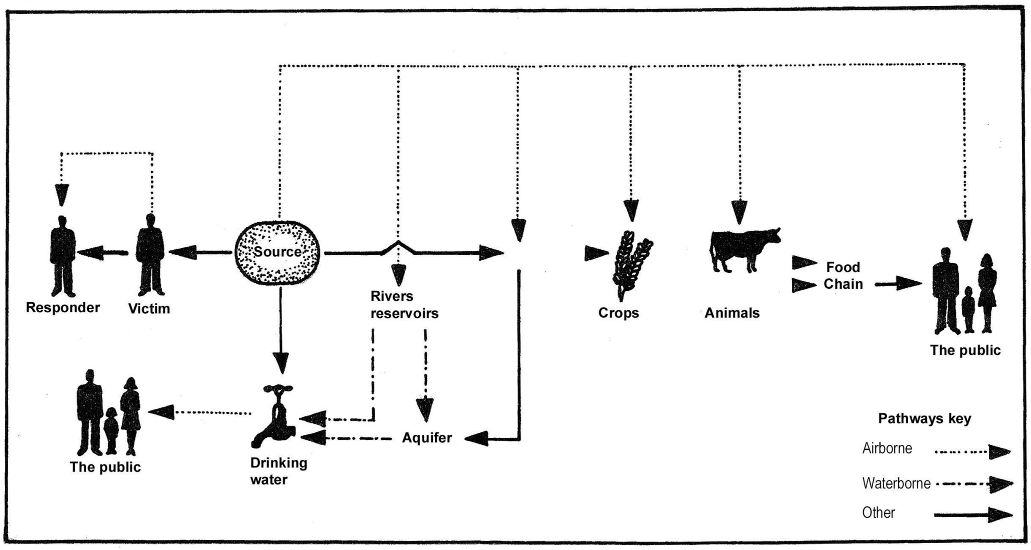
Effects can be local (e.g. burning or blistering of the skin, eyes or respiratory tract) or systemic, and the pattern may be influenced by age, gender, immune state, concomitant exposures and general fitness. Some effects (e.g. eye and respiratory irritation or central nervous system depression) can occur within minutes or hours of the exposure. Other effects (e.g. congenital malformations or cancers) may take months or years to appear.

12.2.2 Public-health effects of chemicals

Stress and anxiety

The occurrence of major chemical incidents has shaped the way members of the public perceive exposure to chemical substances. Such incidents are fear-inducing because they

Fig. 12.1 **Pathways of exposure**[1]



[1] Source: World Health Organization, 1999d.

have the potential to cause large numbers of deaths and illness and because they raise questions about the fragility of technologies over which the public may have little or no control.

Deaths and illness

Large incidents cause considerable numbers of deaths (e.g. the explosion at Bhopal, India in 1984). However, there are many more less-serious incidents which cumulatively have a large health impact (Bowen et al., 2000). These chemical incidents remain unreported unless a specifically designed and targeted reporting system is in place.

Societal and economic costs

Significant economic costs relate to livelihoods, inward investments, and other costs such as closures of health care facilities, schools, factories, etc., litigation and compensation, and helping affected communities recover.

12.3 Operational planning and preparedness

As with responses to all types of disaster, careful planning and thorough preparedness are prerequisites for an effective response to a chemical incident. At the national level, government needs to set up procedures and organizations to ensure that the public-health management of any chemical incident is effective and comprehensive. A national plan should be circulated and discussed widely until agreement has been reached. At the local level, public-health authorities need to identify situations where chemical incidents could occur, and assess the likely health risks to exposed people, property and the environment. The public-health sector needs to be fully involved in the planning and preparedness process, including emergency plan development and implementation. Many organizations will be involved in the planning and response phases of chemical incident management (see Table 12.1).

Table 12.1 **Organizations and groups involved in planning for, and managing, chemical incidents**

Public-health/environmental-health departments and institutes	Public and community groups
Poisons centres	Emergency services/civil defense
Toxicology laboratories	— fire
Local hospitals	— police
Specialist hospitals	— ambulance
Occupational health services	— transport
	— emergency medical responders
Food safety organizations	Military
Local government	Specialist environment agencies
Central government	— rivers
Major local chemical industries	— ocean/sea
Environmental groups, pressure groups and watchdogs	— wildlife
Nongovernmental organizations /Red Cross/Red Crescent	— transport
	— agricultural
	— air quality
	Pollution control agencies
	— factories inspectorates
	Weather services

12.3.1 Multidisciplinary public-health working arrangements

Establishing a multidisciplinary chemical incident team is usually the best way of achieving the necessary tasks, in both the planning and response phases. In addition, if the team enhances their skills with training during the planning phase, the resulting teamwork during an incident is likely to be greatly improved. The geographical area covered by the team needs to be decided, and a coordinating mechanism should be established.

The chemical incident team may be comprised of staff from a number of agencies concerned with health, civil defense and disaster management. The team should also draw upon scientific expertise and should build up good relationships with experts, so that during an incident, help and assistance are speedily obtained.

12.3.2 Vulnerability assessment

Vulnerability assessment, also known as community risk assessment (CRA) in the field of chemical incident management, is an assessment of the potential effects of a chemical incident in the local area. It is comprised of four steps:

- the identification of hazardous chemical sites, pipelines and transport routes;
- the identification of possible incident scenarios and their exposure pathways;
- the identification of vulnerable populations, facilities and environments;
- an estimation of the health impact of potential chemical incidents and the requirements for health-care facilities.

CRA is a complex process and involves a wide range of expertise and agencies. A coordinated approach to data requests and collection is required to produce valid and complete data that meet the needs of the various agencies and experts involved. The public should also be involved. Not only can they provide local knowledge, but their understanding will increase and their anxiety will be reduced when findings are shared. Conducting a CRA develops and strengthens the relationships between the emergency services, the public health services, the chemical industry and the general public. It also helps to identify training requirements.

The identification of hazardous sites in the local community is an important means of recognizing possible emergency situations. Once they are identified, it is possible to check the availability of appropriate expertise, site emergency plans and evacuation, procedures, materials, decontamination equipment and antidotes. There are, however, no generally accepted guidelines for doing this, and it is best to pool ideas and experience from all members of the team.

Ideally, a local inventory should be collated and kept up to date because chemical use may change frequently. For example, chemicals such as fertilizers, swimming pool disinfectants and fireworks are only transported and stored locally at certain times of the year.

12.3.3 Local incident surveillance and environmental monitoring.

For each site identified, the chemicals present (current and planned) are identified and scenarios of possible releases are developed for each one. For each site and substance, the exposure pathways and vulnerable zone (the area to which the contaminants might be transported through air or water) are estimated and mapped out. This can often be done using computer models. It requires a thorough knowledge of the topography of the area, the waterways, the reservoirs and the prevailing climate.

The populations that could be affected within the vulnerable zone are then identified, with an emphasis on any particularly vulnerable groups (children in schools, the elderly in residential facilities, hospital patients, etc.). In addition to the residents of the vulnerable zone, other people in the area at certain times could also be affected, such as workers (both inside the plant and in its vicinity), motorists and visitors to entertainment facilities. Factors that affect vulnerability include the amount and quality of shelter, the access into and out of the site, and people's awareness of risks and response measures.

Facilities and structures in and around the vulnerable zone that provide essential services (e.g. hospitals) and which could be disabled by an incident should be identified. Areas where contamination would have significant effects, such as farmland, water bodies used for leisure activities or wildlife support, and ecologically important sites should be considered.

Assessing vulnerability around chemical transport routes presents greater difficulties, but is extremely important. Highly toxic chemicals are often transported by rail, which passes through densely populated areas, and by inland waterways.

12.3.4 Baseline health assessment

To measure the impact of a chemical release on health, it is necessary to know the background levels of illness in the community before the release.

In most countries, health data are only available at population levels greater than that likely to be affected by a chemical incident. This can make it more difficult to identify any changes in the health of the affected population. To overcome this difficulty, routine data should be collected from populations around the chemical sites. This can be expensive, but should be considered for very high-risk sites. If routine data are not available to produce a baseline measure, a one-off survey may be considered.

In addition, it is helpful to take baseline measurements of chemical biomarkers from the people most likely to respond first to an incident, because they have a long-term risk of exposure. Ideally, these measures should be conducted by the occupational health services. The samples may be frozen and analysed after an incident, together with a post-incident sample, to measure the influence of the chemical incident.

12.3.5 Health impact assessment

This brings together assessment of exposure pathways and degrees of vulnerability in different scenarios to calculate the number and distribution of casualties expected, and the type and severity of possible injuries. The assessment identifies evacuations required in case of acute exposure and considers the effects of secondary contamination. Air dispersion modelling programmes may be used during this process.

It is important to determine the capacity of the local health-care facilities, including toxicology laboratories. Facilities need to be assessed for their patient capacity, medical equipment, decontamination equipment, drugs and antidotes, and number of staff and their level of training. This assessment can be compared with the casualty estimates from the various scenarios, to determine when to call in additional help, or to refer patients to facilities out of the area. These estimates are imprecise, but can help identify the links that need to be established with health facilities in other areas.

12.3.6 Baseline environmental assessment

Air, water, soil, sediment and food in the vicinity of chemical plants should be sampled and tested for the full range of chemicals (or their by-products) being manufactured, used or stored. Laboratory services should be identified for this task. Priority areas may need to be selected from the CRA and targeted. It may be helpful to carry out a complete environmental assessment, to predict the levels of environmental contamination from a variety of likely release scenarios. There are various computer dispersion models available for this purpose, though many of these models are unable to take sufficient account of all the relevant variables.

12.3.7 Liaison with the local community

The people who live and work in the area that could be affected by a chemical release should not only be informed about the plans for a chemical incident, but should also be involved in drawing them up. Community members who help with these preparations must represent their local community.

Large public meetings

This is the most common and familiar way of initiating face-to-face discussions with the public, though it is often one of the least effective ways to institute a dialogue. However, public meetings can be beneficial if the officials involved are knowledgeable about the local risks and skilled in risk communication.

Public availability sessions

Although time consuming and resource intensive, a personal and confidential discussion between a concerned individual or family and a health professional is perhaps the most effective way to discuss risk issues. Public availability sessions are publicized and hosted by public-health agencies in the local community; experts are available to talk with all interested individuals, either by appointment or on a first-come, first-served basis.

Community advisory panels

Community advisory panels (CAPs) provide the opportunity for an effective dialogue between community representatives, health officials and chemical industry representatives. They help ensure continuity over a period of months or years, and the opportunity for mutual education.

CAPs typically comprise 12–15 community representatives, chosen either by self-nomination or by community organizations. The panels, whose members represent the widest possible spectrum of community interests, usually meet every 3 months in a public forum. Rules regarding the conduct of meetings and issues to be covered are agreed upon at the outset.

Public warning systems

Once an incident has occurred, there is a need for robust warning systems for informing the public of the incident and of any protective measures they should take. For example, a warning system may involve sounding a siren, so the public know they should listen to the radio for information and instructions. This can be very effective and is appropriate for high-priority areas, though the public need training and updating in the process.

Other mechanisms for public interaction

Site visits can help the community to understand the measures taken by the industry to protect the workers and the public. Mass mailings are an efficient way to notify residents of a concerned community about new scientific findings, planned activities or upcoming meetings. These are most effective when they are done in a one-page, "fact sheet" format with bulleted information. Information sheets are also helpful in providing information about the priority sites and their chemicals, warning formats and protective actions to be taken. Radio and television can be very effective media, depending on local availability.

12.3.8 Public-health plans for chemical incidents

Planning for major incidents and disasters has been comprehensively developed throughout much of the world. In most countries, there is a general plan covering major incidents and disasters. In addition, there is often a general plan covering the roles of the emergency services in chemical incidents. There are usually also major incident plans in hospitals that cover most types of incidents. However, public-health plans to deal with chemical incidents are usually nonexistent or poorly developed.

The public-health chemical incident plan needs to take account of four different scenarios:

- — a release from a fixed site: this will usually be a registered hazardous site;
- — a detected release of a known chemical from a non-fixed site such as a road tanker (which may not be clearly labelled as carrying hazardous material);
- — a detected release of an unknown chemical: typically, this will occur in releases from sites not on the hazardous site inventory, or with unknown combustion products from a chemical fire;
- — a silent release, where the release is unknown or suspected from other routes.

The plan will also be significantly improved if key members of the local community are involved throughout the process. Extensive evaluation of the plan and its implementation should be carried out after every incident or training exercise.

12.3.9 Databases

At the time of an incident, it is vital to have rapid access to data about the chemical. It is important therefore that the chemical databases are purchased and installed, or that uninterrupted access to databases is established well before an incident. The data required include:

— the physical characteristics of the chemical (these influence the way it disperses in the environment and how it enters the body);
— the biological tests available to detect exposure and/or adverse health effects;
— environmental sampling techniques and equipment needed;
— lists of antidotes and decontamination procedures;
— medical signs and symptoms and methods of treatment.

12.3.10 Reducing the probability of incidents

The CRA may have identified sites and procedures where improvements could lessen the probability of an incident occurring. Often, some of these improvements can only be made by the company producing, storing or transporting the chemical, and it may require a multi-agency team to negotiate these changes.

12.3.11 Reducing the health risks of incidents

Common measures to reduce the health risks of chemical incidents include:

— locating chemical sites away from centres of population;
— registering all chemicals in commercial establishments with a hazard inventory to ensure rapid identification of the released chemical;
— regularly evaluating plans and their implementation;
— storing reduced amounts of chemicals;
— clearly labelling all chemicals in transit;
— rapidly notifying the chemical incident emergency services in the event of a chemical release;
— regularly surveying and standardizing the reporting of incidents, including small “routine” ones;
— decontaminating land or water already contaminated by waste disposal;
— preventing or containing water run-off from fire-fighting;
— constructing drainage ditches or holding tanks to contain leaked liquid chemicals.

12.3.12 Establishing routine procedures

Routine procedures to be established are described in this section.

Recognizing chemical incidents

Detection can occur in the following ways:

- The polluter informs the emergency services, who inform the public-health services.
- The release itself is observed—often as a major event, such as an explosion or oil tanker disaster.
- The public provide information about environmental indications (e.g. colour, smell or eye irritation).
- There is an ad hoc observation of a rise in an environmental contaminant.
- Routine environmental monitoring data show a rise in a contaminant.
- Clinicians and others (e.g. poisons information centres) are presented with a sudden rise in an unusual health problem.
- Routine health monitoring data show a rise in a sentinel health event or other health measure.

A programme for recognizing chemical incidents therefore requires the public, local institutions and organizations, and all members of the emergency, environmental and health services to be regularly alerted to the possibility of chemical incidents, and to be educated on the means of communicating rapidly with each other and with the chemical incident team. It also requires a surveillance and monitoring system, a chemical incident network coordinator who is always available, and a well-publicized, twenty-four hour incident telephone line.

Conducting population health surveillance

Routine population health surveillance related to chemical incident management is the ongoing and systematic collection, analysis and interpretation of health data in order to do the following:

— identify a health event that may be related to an unknown, acute release of a chemical;
— monitor trends in health status markers;
— stimulate epidemiological research likely to lead to control or prevention;
— permit assessment of control measures.

General health statistics

Data from a wide variety of routine sources need to be collated and presented in a way that allows trends to be identified and comparisons to be made. This requires data that are reasonably accurate, comprehensive, up-to-date and easily accessible. To calculate incidence rates and exposure rates it is essential to first define the population. In an emergency, a rapid estimate of the population by direct counting, or sampling and extrapolation, is usually more reliable than census figures or other established data.

Mortality statistics

Most countries have systems for registering deaths, usually with information about cause of death. However, inaccuracies may occur at any step in the chain of procedures leading to the production of mortality statistics, and staff should ascertain the degree and type of inaccuracies associated with the data they use. Nevertheless, trends in mortality figures may indicate a health event related to an unknown chemical incident.

Health centre data

In many countries, hospital admissions are the main source of data about illness and disability. Usually, however, the data about patients are not related to geographical areas. For medical conditions of particular concern, the population admission rates need to be calculated by searching the records of all the hospitals that the patients might have been admitted to.

It is also important to set up links with outpatient services, private practice, accident and emergency care, and other primary-care facilities, so that in the event of a chemical incident, rapid contact can be made to ascertain numbers of people attending for primary care.

Cancer registration

Cancer registries have been useful in identifying spatial and temporal clusters of cancers and sometimes in allaying public fears about the existence of clusters surrounding chemical plants. However, there are significant problems in using cancer as a potential end point for environmental health assessments. There is a long latency between exposure and disease onset, 30 years or more, which makes it difficult to conduct follow-up studies on exposed populations long enough to detect cancer onset. This is usually compounded by a lack of accurate information on the exposures of people with cancer. Cancer data have been useful for assessing chronic exposures, but their usefulness in identifying acute exposures has yet to be demonstrated.

Congenital malformations
Population-based registries have been set up in some countries both for research into the cause of congenital malformations and to detect changes in the frequency of different classes of congenital disorder. Experience with the use of these registries, however, has shown that recognition and registration of the malformations is quite a slow process, and it is not feasible to use them to identify chemical incidents. Congenital malformations registers may be more useful for prospective assessment of the population health effects after known incidents of exposure, by linking new entries in the congenital malformation register with the population of exposed people.

12.3.13 Conducting exercises and training

Training and education play an important part in preparedness for, and response to, chemical incidents. The emergency services, other relevant health professions, local chemical plants, etc. need to train their personnel to properly manage occurrences that might grow to become chemical incidents, as well as chemicals incidents themselves, to understand the responsibilities of other professionals, and to minimize the risks to the workers and members of the public.

It is important that all those with specific responsibilities in a chemical emergency response should receive joint theoretical and practical training in the use and implementation of jointly agreed emergency response plans. This will enable them to become familiar with taking part in a broad cooperative effort to respond to a chemical incident.

Core training for the response team is an important mechanism for the various agencies' staff to get a good understanding of their own and others' needs. Public-health elements that should be included in the core training are:

- risk and exposure assessment;
- epidemiology and toxicology;
- emergency actions and procedures to reduce risk to responders and the public;
- the use of protective equipment;
- shelter and protective measures and procedures;
- biological and environmental sampling;
- the key components of a major chemical hazard control system;
- risk communication techniques;
- regular exercises.

Public-health and environmental-health staff require specialist training to a higher level in the relevant core areas. Countries need to review how to establish access to comprehensive training for all health professionals concerned. This may be organized through public-health training centres, poisons information centres, national information and advisory centres, or local response units.

Exercises should be used to maximize the effectiveness of training. There are four main types of exercise: orientation, tabletop, functional and full-scale simulations. Individual agencies may also consider holding preliminary orientation exercises to introduce participants to their responsibilities under the chemical incident plan, and to prepare them for the exercise.

Orientation exercises

An orientation exercise acquaints staff in a single discipline with policies and procedures in the chemical incident plan, and provides a general overview of the plan provisions. It is particularly effective in ensuring that personnel understand their roles and responsibilities and how to access background information and specialist advice. It also helps to clarify any complex or sensitive elements of the public-health chemical incident plan.

The orientation exercise does not generally involve any direct simulation, but is used to review procedures and informally apply them to potential emergency situations, preferably those involving priority sites and chemicals.

Tabletop exercises

A tabletop exercise is more formally structured and often involves more than one sector with responsibilities under the plan. Prepared situations and problems are combined with role-playing to generate discussion of the plan, its procedures, the resources that can be called on, and the policies to be adhered to when making decisions. Tabletop exercises are a good method of familiarizing individuals and groups with their roles and demonstrating proper coordination. They provide a good environment within which to reinforce the logic and content of the plan and to integrate new principles into the decision-making process. Participants are encouraged to act out critical steps, recognize difficulties, use the expertise of the other sectors represented and resolve problems. Tabletop exercises usually take 2–4 hours and require specially trained facilitators.

Functional exercises

A functional exercise is an emergency simulation designed to provide training and evaluation of integrated emergency operations and management. More complex than a tabletop exercise, it focuses on the full-scale interaction of decision making and agency coordination involving a typical incident. All field operations are simulated; information about activity is transmitted using communications equipment, including radio and telephone. It permits decision makers, off-site incident coordinators, on-site incident managers, and operations personnel to practise emergency response management in a realistic situation with time constraints and stress. It generally includes several organizations and agencies, practising interaction of a series of emergency functions. These may include: initial information gathering from the incident hotline; deciding the make-up of the core team; direction and control off-site; communications to be made with those on-site; and access to databases and mobilization of specialists, to provide advice, public warnings and decisions on evacuation.

Full-scale simulation exercises

A simulation exercise focuses on several components of an incident response and management system simultaneously. It includes the interactive elements of a community emergency programme, similar to the functional exercise, but also uses a detailed scenario to simulate an emergency. The exercise includes practicing on-site direction and operations, and also includes coordination and policy-making roles at the incident coordinating centre. Direction and control, mobilization of resources, communications, assessment, decontamination, treatment, triage and other special functions are commonly exercised.

An audit of the various exercises will enable the chemical incident plan to be updated and improved, and for training requirements to be identified. An audit should ask the following questions:

- **Plans:** did the plans work and are there any improvements to be made?
- **Teamwork:** how did the individual team members act in the group, and interact with each other?
- **Decisions:** did the team reach the right conclusions and make the right recommendations in light of available data?

12.3.14 Conducting national chemical incident surveillance and contributing to international chemical incident surveillance

Important public-health lessons can be learned from an analysis of an actual incident and any epidemiological study conducted following it. In the same way, important lessons can be learned from collating data about the range of incidents that occur within a country and around the world.

The data should make it possible to do the following:

— map the production, storage, transport and use of chemicals;
— detect trends in the occurrence of different types of chemicals commonly involved in incidents;
— provide estimates of the scale of morbidity and mortality related to the chemical incidents;
— stimulate epidemiological research likely to lead to control or prevention;
— identify risk factors associated with the occurrence of chemical incidents;
— permit assessment of control measures;
— improve the practice of staff who manage the surveillance system;
— pinpoint additional expertise, training, resources and facilities needed to deal with incidents in the area;
— stimulate governments to initiate proper incident control mechanisms at the international level.

12.4 Dealing with chemical incidents

In any chemical incident, there are essential steps to take as part of the chemical incident plan. These are described below in approximate chronological order.

12.4.1 Alerting the health-care services

Public-health/environmental-health professionals are in a good position to assess the extent of the casualties and to alert and activate local and more distant health-care facilities. This will involve providing accident and emergency departments with information about the nature of the chemical(s) and any precautions to be taken, and information about secondary contamination and how to decontaminate casualties, staff and equipment.

12.4.2 Best outcome assessment/estimation

Once a chemical incident has occurred, there are a number of courses of action or management options that can be taken at different points in the sequence of events. A management option can be any choice available to the emergency responders, such as whether to extinguish a fire or let it burn out, whether or not to use a chemical dispersant following an oil spill, or whether to evacuate people from an affected area or recommend sheltering.

Each of these management options may end up with a different outcome on the health of the public, the responders and the environment. Chemical incident response staff, for example, will be primarily concerned with containing the chemical, while hospital doctors will be dealing with the casualties, and neither will be able to view the incident from a distance or in the long term. The function of the chemical incident team is to try to work out the management option that arrives at the best outcome for the health of the public and the environment. The accuracy with which this can be done depends on the amount of information and data that arrives from the incident site, and the amount of time available before a decision is required.

12.4.3 Information and public warnings—communication skills

The public often needs information about:

— the incident;
— measures being taken to contain the release;
— who is currently under threat;
— the health effects of exposure;
— what the public can do to protect themselves;
— when, where and how further information will be made available.

Public warnings and directives must be clear and repeated. Often this is done through the media, but may also be conducted through public-address systems. All public information must be consistent, and should be provided by a small number of people with strong communication skills and training.

12.4.4 Advice on protection

Proper assessment during the incident can determine whether individuals or a population are likely to be exposed, and the possible health effects of short-term, acute and chronic exposure. This assessment may be done by the emergency services for populations near the incident site, or by the chemical incident team for more distant populations.

12.4.5 Sheltering or evacuation/removal.

For the public, usually the most feasible protective measure is sheltering—i.e. staying in a building, closing all the windows and doors, and shutting down any ventilation or air-conditioning systems until the chemical (usually in a cloud) has passed. This procedure will usually protect the population for about 2 hours, which is more than enough for the majority of incidents.

Evacuation often involves complex arrangements for providing transport, shelter, food, water and appropriate medical care. It may also require ensuring the security of the properties left uninhabited. See Section 4.2 for further information on evacuation.

Evacuation may be the better option in one or more of the following cases:

— the chemicals are widely dispersed and contamination is extensive;
— toxic chemicals are suspected, but cannot be identified readily;
— the chemical is highly hazardous;
— the air will be hazardous for a prolonged period.

The decision on whether to evacuate people or encourage them to seek protection by sheltering must be based on a balance of the risks of the two options, with the primary consideration being the risk of exposure (both level and duration).

12.4.6 Other restrictions to protect health

If soil is contaminated, it may be necessary to restrict movement through the contaminated area. People should be kept upwind of an air-contamination site, or away from any plume of smoke or dispersion cloud. Modelling and monitoring should be carried out to determine whether groundwater movement has dispersed the contamination over a wider area or contaminated water supplies. Other measures include restricting the distribution or use of contaminated crops, livestock or drinking-water. Alternative supplies need to be identified and provided in this case.

12.4.7 Organizing registers and samples

There are three important steps that have to be taken to organize a register of data on exposure to the chemical(s) of concern:

— entering details of all the exposed people into a register;
— taking samples from the people in the register;
— taking samples from the contact medium (e.g. the soil, water or air) these people were exposed to.

Environmental modelling or rapid environmental sampling may make it possible to ascertain the media that have been contaminated and their geographical distribution, and the populations likely to have been exposed.

By collecting these data it will be possible to:

— ascertain when the risk of exposure in certain areas falls below the threshold for protective action;
— ascertain the populations and individuals requiring further follow-up and treatment;
— supply baseline data for long-term follow-up studies;
— assess the success of mitigation efforts;
— add to the understanding of the incident and exposure effects;
— uncover continuing problems;
— provide estimates for planning and resource allocation, using data on the distribution and severity of health effects, and on the environmental effects;
— support environmental and community remediation efforts;
— develop reference background material for future similar incidents and add to toxicological databases;
— refine the theoretical models of assessment;
— provide information for litigation and compensation.

Ideally, all named registers should contain details of the person, exposure time, exposure route, portal of entry, symptoms and biomarkers. Named registers require a set of agreed definitions, permission from the individuals concerned, confidentiality assurance, an updating mechanism, and a commitment of time and resources, which can be considerable.

12.4.8 Collection of samples—biomarkers of chemicals and their effects

Biological measurements, both of exposure and of the effects of exposure, can be an important tool. Unfortunately, and contrary to widespread misconceptions, no single blood test will identify which of the thousands of chemicals in the world an individual has been exposed to. Testing for biomarkers of exposure and biomarkers of effect requires specific sampling and handling techniques for each chemical or class of chemical, and many of the tests can only be carried out in specialist toxicology laboratories (World Health Organization 1993c).

Biomarkers of exposure

These are measurable levels of the parent chemical or its metabolites found in one or more body fluids or tissues in an exposed population. Sensitive, replicable assays for the human body burden of many contaminants are available, but often must be performed soon after exposure.

If elevated levels could be caused by factors other than exposure to the agent of concern, it is important that information be gathered on hobbies, secondary occupations, source of water supplies, and any other determinants with elevated levels. It may be possible to compare the target population to a reference population that resembles the exposed population, except for the exposure. Reference levels exist for many tests.

A preliminary exposure survey should test samples from the subgroup most likely to be highly exposed to contaminated environmental media (exposure biomarkers), or most vulnerable to exposure (effect biomarkers). If samples from these groups do not show measurable levels, it is unlikely other individuals in the wider population will have been exposed, and further investigation of other exposed people is unlikely to be fruitful.

Biomarkers of effect

For many contaminants or situations, it is not possible to study biomarkers of exposure. In some cases, this is because the half-life within the human body is short. In other cases, it is because laboratory tests are not available, or that the chemical does not enter the body and has only a local effect. In such circumstances, it may be possible to measure intermediate health effects of exposure by using physiological measurements known to change with exposure.

If biomarkers have not been taken or are not available, levels may need to be inferred from:

- occupation, and specific place and type of work;
- special features of exposure, such as working in a confined space or the level of ventilation;
- whether indoors or outdoors at the time and the level of physical activity;
- the volume of chemical used in a process (e.g. volume of paint containing mercury used in a home);
- immediate symptoms, such as burning or itching, that may indicate the level to which an individual has been exposed to the chemical;
- time from exposure to onset of symptoms—a rapid onset may indicate a high dose;
- special features that may affect absorption within the body (e.g. smoking, exercise or abrasions);
- measures taken to reduce contamination of the individual (e.g. washing skin and clothes immediately);
- scorching of vegetation or animal sentinels.

12.4.9 Environmental monitoring

Monitoring at the source of contamination should continue well beyond the moment at which the release is thought to have been controlled, to ensure that it has indeed been controlled.

It may be that some modelling of the likely distribution of the chemical has already been done. If so, it may be useful to check its accuracy by sampling outside the predicted contaminated zone. This is particularly important if there are reports of health effects in these areas.

It is also important to assess the concerns of the community about the possible contamination of their environment and their own exposure. These may point to areas for further study or remediation, and may also guide the presentation of the results of the investigation, to demonstrate how community concerns have been addressed.

12.5 Assessing the impact on public health

The main objectives of assessing the health effects of a chemical incident on the public are as follows.

- ***To offer advice about exposure and protection***: information is needed from the incident on the source and type of chemical, and on the likely exposure pathways; and information is needed from databases about the type, frequency and severity of the health effects of the chemical (ideally, at different concentrations of environmental contamination).
- ***To offer advice about treatment***: all those exposed, or suffering from acute health effects need to be identified and followed up for as long as necessary.
- ***To contribute to the public health toxicological information base***: it is important to set up epidemiological studies for gathering data on the health effects of chemical concentrations seen in acute exposures, since the evidence base is limited.

12.5.1 Health impact assessment

The methods used to assess the impact on public health vary depending on the stage of the incident.

Stage 1. Preparedness

During the planning and preparation stages, public-health/environmental-health professionals should become familiar with the sources of data on exposure and health risk and effect.

Stage 2. Rapid health-risk assessment

During the acute stage of an incident, a rapid health-risk assessment must be conducted. Initially this can be done using models to predict health effects, based on information gathered from other exposures.

Stage 3. Exposure assessment

The next method is to start assessing the exposure levels. This involves four principle methods (United Kingdom Department for Environment, Food and Rural Affairs, 1999):

— environmental and personal/biological monitoring;
— questionnaires of activity and movement in relation to the contaminant;
— modelling the incident source, chemical dispersion from the source and population exposure;
— assessing markers, often using other indicators, such as animal sentinels.

Stage 4. Assessment of acute health effects

The next stage is to start assessing the acute health effects. This involves gaining data on toxic and stress-related effects and their functional, physical, morbidity and mortality outcomes. Advice can be given on protection, treatment and follow-up.

Stage 5. Assessment of longer-term health effects

Similar data on the longer-term health effects can be collected, although this demands considerable commitment and resources from both the agencies and the public.

Stage 6. Epidemiological studies

The short- and long-term health effects can be identified using epidemiological studies correlated to the causes. Large-scale analytical epidemiological studies are expensive in time and resources. Descriptive studies requiring fewer resources can be used to assess

Table 12.2 **Different types of epidemiological study**

Analytical studies	Descriptive studies
Panel studies	Ecological studies
Cohort studies	Cluster investigations
Case-control studies	Disease and symptom prevalence studies
	Cross-sectional studies

the feasibility of a major study, address the concerns of the public, and generate hypotheses for further studies. Different types of analytical and descriptive epidemiological studies are listed in Table 12.2.

12.6 Further information

For further information on chemical incidents and health, see: United States Environmental Protection Agency (1990), World Health Organization (1990), United Nations (1991), Organisation for Economic Co-operation and Development (1992), Sullivan & Krieger (1992), Olson & Mycroft (1994), Organisation for Economic Co-operation and Development/United Nations Environment Programme (1994), United States Federal Emergency Management Administration (1994), van Leeuwen & Hermens (1995), European Commission (1996), Organisation for Economic Co-operation and Development (1996), United States Department of Transportation (1996), Ackermann-Liebrich et al. (1997), Lillibridge (1997), United Nations Environment Programme (1998), World Health Organization (1999d), Berglund, Elinder & Järup (2001).