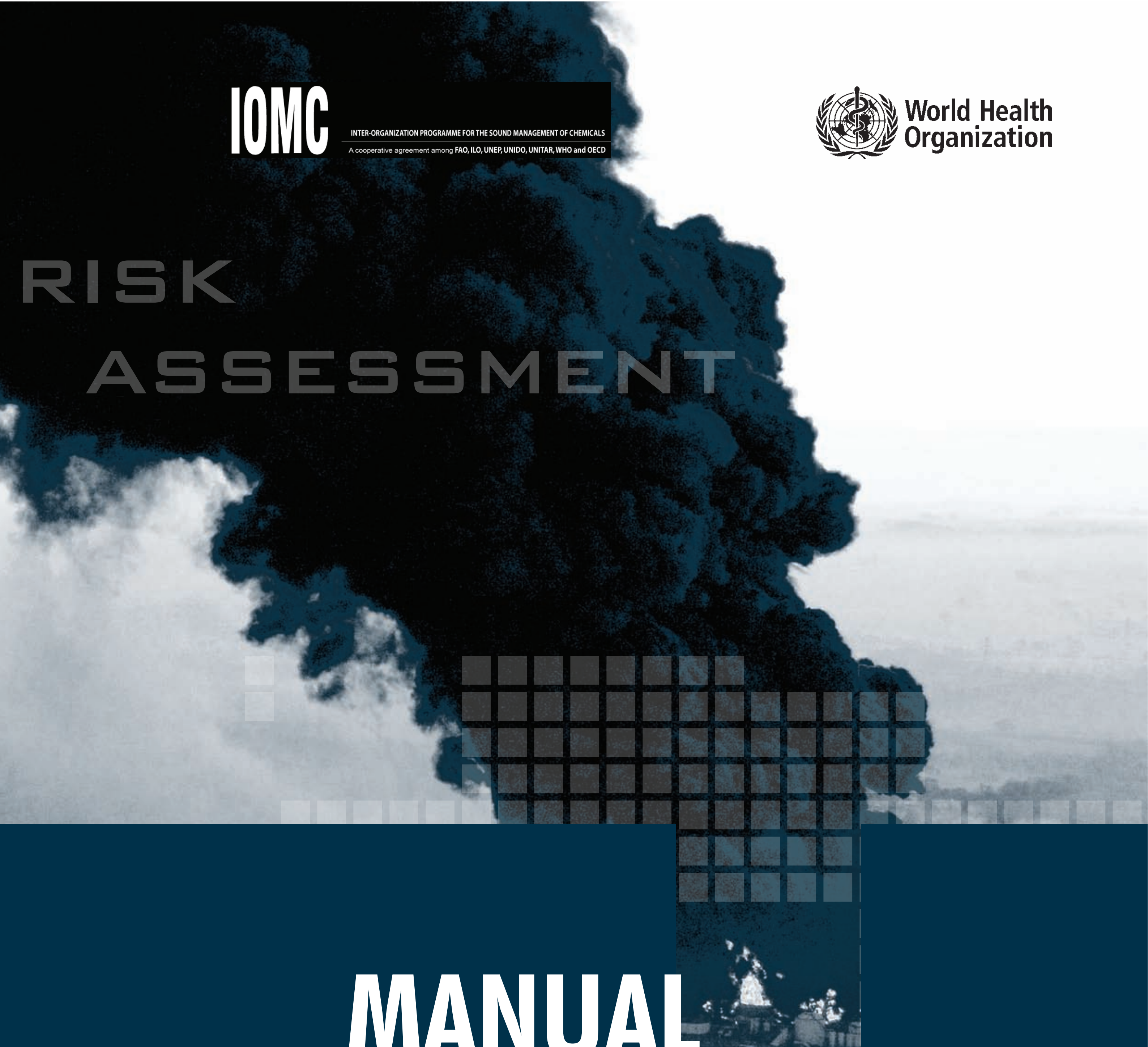
IOMC

INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among FAO, ILO, UNEP, UNIDO, UNITAR, WHO and OECD

World Health Organization



RISK ASSESSMENT

MANUAL for the Public Health Management of Chemical Incidents

EMERGENCY PLANNING

World Health Organization

MANUAL

for the Public Health Management of Chemical Incidents

This publication was developed in the IOMC context. The contents do not necessarily reflect the views or stated policies of individual IOMC Participating Organizations.

The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The participating organisations are FAO, ILO, UNEP, UNIDO, UNITAR, WHO and OECD. The World Bank and UNDP are observers. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

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PREFACE

Chemical releases arising from technological incidents, natural disasters, and from conflict and terrorism are common. The International Federation of the Red Cross has estimated that between 1998 and 2007, there were nearly 3 200 technological disasters with approximately 100 000 people killed and nearly 2 million people affected. The production and use of chemicals is predicted to increase worldwide, and this is particularly true in developing countries and those with economies in transition where increased chemical extraction, processing and use is closely tied to economic development. An ever increasing dependency on chemicals requires the health sector to expand its traditional roles and responsibilities to be able to address the public health and medical issues associated with the use of chemicals and their health effects.

A number of important international initiatives have recently been undertaken that require countries to strengthen capacities in relation to the health aspects of chemical incidents and emergencies:

In 2005, the revised International Health Regulations (IHR (2005)) were adopted by the World Health Assembly. Entering into force in 2007, IHR (2005) is a legally binding agreement contributing to international public health security by providing a framework for the coordination of the management of events that may constitute a public health emergency of international concern, and for strengthening the capacity of all countries to detect, assess, notify and respond to public health threats. Initially developed for certain infectious diseases, the revised IHR (2005) also covers those public health threats involving chemicals.

In 2006, the Strategic Approach for International Chemicals Management (SAICM) was adopted by the International Conference on Chemicals Management. SAICM provides a policy framework to promote chemical safety around the world, including many aspects of chemical incident prevention and preparedness. It comprises the Dubai Declaration expressing high-level political commitment to SAICM and an Overarching Policy Strategy which sets out its scope, needs, objectives, financial considerations, underlying principles and approaches and implementation and review arrangements. The Declaration and Strategy are accompanied by a Global Plan of Action that serves as a working tool and guidance document to support implementation of the SAICM.

The purpose of the *WHO Manual for the Public Health Management of Chemical Incidents* is to provide a comprehensive overview of the principles and roles of public health in the management of chemical incidents and emergencies. While this information is provided for each phase of the emergency cycle, including prevention, planning and preparedness, detection and alert, response and recovery, it is recognized that the management of chemical incidents and emergencies require a multi-disciplinary and multi-sectoral approach and that the health sector may play an influencing, complementary or a leadership role at various stages of the management process. The target audience includes public health and environmental professionals, as well as any other person involved in the management of chemical incidents.

WHO and all those involved in the development of the publication hope that the publication will have wide application, especially in developing countries and countries with economies in transition, and that in the future the health sector will be better prepared to acknowledge and fulfil its roles and responsibilities in the management of chemical incidents and emergencies, thereby contributing to the prevention and mitigation of their health consequences.

PROCESS FOR DEVELOPMENT OF THE MANUAL

Dr K. Gutschmidt, WHO Secretariat, served as the Responsible Officer for the development of this manual including its scientific content.

An editorial group of scientific experts was convened by WHO to provide oversight, expertise, and guidance for the project and to ensure its scientific accuracy and objectivity. Editorial members included Professor G. Coleman (Director, WHO Collaborating Centre for the Public Health Management of Chemical Incidents, Cardiff, United Kingdom), Professor S. Palmer and Dr D. Russell (both Health Protection Agency, United Kingdom). The editorial group met several times in Cardiff and Geneva during 2007–2009 to define the scope, content and structure of the manual, to review and discuss the content and to oversee implementation of the project.

The first draft was prepared by Dr D. MacIntosh (Environmental Health & Engineering, Newton, MA, USA) and posted on the internet for peer-review in February 2007. In addition, a review meeting taking into account comments received was held on 23–25 April 2007, Beijing, China. The meeting was attended by Professor G. Coleman (chair), Dr A. Dewan (National Institute of Occupational Health, Ahmadabad, India), Dr Jin Yinlong (National Institute for Environmental Health and Product Safety, Beijing, China), Professor Li Dehong (National Institute for Occupational Health and Poison Control, Beijing, China), Dr D. MacIntosh (Environmental Health & Engineering, Newton, MA, USA), Dr I. Makalinao (University of the Philippines, Manila), Professor S. Palmer (Health Protection Agency, United Kingdom), Dr M. Ruijten (National Institute for Public Health and the Environment RIVM, The Netherlands), Dr D. Russell (Health Protection Agency, United Kingdom), Dr R. Soulaymani Bencheikh (Centre Anti-Poisons et de Pharmacovigilance, Rabat, Morocco), Dr W. Temple (National Poisons Center, University of Otago, Dunedin, New Zealand), Professor Ding Wenjun (Chinese Academy of Sciences, Beijing, China), Professor Zhao Xinfeng (State Environmental Protection Administration, Beijing, China) , Mr M. Barud Ali (Hargheisa, Somalia), Dr Woo Zhen (China Centers for Disease Control, Beijing), Mr. J. Abrahams (Asian Disaster Preparedness Center, Pathumthani, Thailand), Dr Jinag Fanxiao (WHO Office, Beijing), Professor J. Spickett (WHO Office, Beijing), Ms J. Tempowski (WHO, Geneva), and Dr K. Gutschmidt (WHO, Geneva).

The second draft was prepared by Dr D. MacIntosh and Dr M. Ruijten (CrisisTox Consult, the Netherlands) taking into account the recommendations received from the Beijing meeting and it was reviewed by the editorial group in London, 18–19 February 2008. The final draft document was edited by Ms Susan Kaplan and the layout was designed by L'IV Com Sàrl.

ACKNOWLEDGEMENTS

The contributions of all who participated in the preparation and finalization of the *Manual for the Public Health Management of Chemical Incidents and Emergencies*, including those who have provided their comments during the peer-review process, are gratefully acknowledged. In addition, WHO gratefully acknowledges the financial support provided by, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany, and the Health Protection Agency of the United Kingdom.

1 INTRODUCTION

On 2–3 December 1984, the city of Bhopal, India, was hit by what is still believed to be the worst chemical incident in history. The hundreds of thousands of people affected by the Bhopal incident were victims of a combination of circumstances that made any potential incident in the industrial facility that produced pesticides particularly dangerous. This deadly combination of circumstances could have been avoided if a number of well-established security and safety principles had been followed before, during and after the chemical incident.

As described below, the purpose of this manual is to provide information that will help countries minimize the health risks of chemical incidents, such as the Bhopal disaster, by raising awareness of their health impacts and by providing suggestions for preventing and managing their occurrence.

1.1 THE OBJECTIVE OF THIS PUBLICATION

The prevention and mitigation of chemical incidents and their health consequences is a broad field requiring specialists from many backgrounds. Public health has an essential role to play in preventing the occurrence of chemical incidents, and minimizing their negative impacts on both the exposed population and the environment should they occur. The purpose of this document is to introduce principles and recommendations about the public health role in prevention and mitigation of chemical incidents. The target audience is public health and environmental professionals and policy-makers, as well as any party involved in the management of chemical incidents.

This publication will help facilitate the effective fulfilment of such public health involvement, including by establishing or refining the public health role in the development of a preparedness plan for management of chemical incidents and to enhance capacity planning and assessment for chemical incidents. This document can also be used as an aid to improve the performance of all professionals with responsibility for managing risks posed by chemical incidents. While this manual presents the principles and functions of the public health management of chemical incidents, the specific organizations or government agencies that carry out these functions may vary between countries.

Chemical incidents can manifest in many forms and scenarios (see section 1.2) including any number of environmental media such as food, water, air, soil, consumer products and types of source such as fixed sites, vehicles and natural events. An attempt to cover all of these in detail would make the publication complex and possibly inaccessible. The focus of this publication is on chemical incidents resulting from fixed sites or transportation with the potential to result in chemical exposure of communities. The text has been designed to describe this category of incidents. Regardless of the initiating event, the general characteristics of such incidents are the sudden, unexpected and uncontrolled occurrence of a chemical release or outbreak of illness that may have a very dynamic time course.

The manual comprises five main sections:

- Section 2.0 PREVENTION focuses on general measures that can be taken to diminish the likelihood of a chemical incident and to limit its severity.
- Section 3.0 EMERGENCY PLANNING AND PREPAREDNESS details broad goals that can be accomplished to ensure adequate public health preparedness of all involved parties to respond to a chemical incident.
- Section 4.0 DETECTION AND ALERT describes various channels that can be used to detect a chemical incident and to alert the stakeholders involved in a chemical event emergency.
- Section 5.0 RESPONSE deals with the public health tasks that should be carried out during an emergency.
- Section 6.0 RECOVERY details the methods used to evaluate the causes and responses to chemical

CASE STUDY 1: THE BHOPAL GAS INCIDENT – BHOPAL, INDIA

The night of 2–3 December 1984 in Bhopal, India, was one of those nights where the weak winds kept changing direction. Under the clear dark sky, the key units of the Union Carbide India Limited facility, one of the largest employers in the city, were quietly waiting to be dismantled and shipped to another developing country.[a]

The Union Carbide plant had once been part of an ambitious Indian plan to achieve self-sufficiency in agricultural production by increasing the national production of pesticides, but the plan was severely curtailed by the crop failures and famine that spread across India in the early 1980s. The rising level of farmers' indebtedness dramatically decreased investments in expensive pesticides, and the plant was now operating at only one quarter of its production capacity.

At 23:00, while most of Bhopal's 900 000 inhabitants were sleeping, an operator at the Carbide plant noticed a small leak as well as elevated pressure inside storage tank 610, which contained methyl isocyanate (MIC), a highly reactive chemical used as an intermediate in the production of the insecticide Sevin. The leak had been created by a strong exothermic reaction resulting from mixing of one tonne of water normally used for cleaning internal pipes with 40 tonnes of MIC contained in the tank.

Because coolant for the refrigeration unit had been drained previously for use in another part of the plant, tank 610 could not be cooled quickly. Therefore, pressure and heat continued to build inside the tank and the tank continued to leak. Both the vent gas scrubber and the gas flare system, two safety devices designed to neutralize potential toxic discharges from the tank before they escaped into the atmosphere, had been turned off several weeks before. At around 1:00, a loud rumbling echoed around the plant as the safety valve of the tank gave way. Nearly 40 tonnes of MIC gas were released into the morning air of Bhopal. It did not take long for the plume, carried by the changing winds, to spread over a large area.

At least 3800 people died immediately, killed in their sleep or during the flight that ensued. Local hospitals were soon overwhelmed with the thousands of injured people. The crisis was further deepened by a lack of knowledge of exactly which gas was involved and hence what the appropriate course of treatment should be. Estimates of the number of people killed in the first few days by the plume from the Union Carbide plant are as high as 10 000, with 15 000 to 20 000 premature deaths reportedly occurring in the subsequent two decades. The Indian government reported that more than half a million people were exposed to the gas. The greatest impact was on the densely populated poor neighbourhoods immediately surrounding the plant.

The Bhopal incident was the result of a combination of legal, technological, organizational and human errors. While the immediate cause of the incident was the unintended release of a large amount of water into a storage tank, the severe health effects of the chemical reaction that ensued were certainly aggravated by the failure of the various safety measures and the lack of community awareness and emergency preparedness. Economic pressure faced by industry, communities and governments can be a contributing factor that influences the likelihood and severity of a chemical incident.[b]

a Broughton E. The Bhopal disaster and its aftermath: a review. *Environmental health: A global access science source*, 2005, 4:6 doi:10.1186/1476-069X-4-6.
b *TED case study: the Bhopal disaster* (http://www.american.edu/ted/bhopal.htm).

incidents and to follow up the victims in order to learn from the experience of incidents and near incidents, and to restore and remediate the affected environment.

1.1.1 The epidemiology of chemical incidents

Since the middle of the twentieth century, chemicals have played an increasing role in the worldwide economy. Currently, more than 15 million chemical substances are commercially available.[1] Approximately 60 000 to 70 000 chemical substances are in regular use[2] and between 200 and 1000 chemicals are produced in excess of one tonne annually. In addition to chemical manufacturing, management of chemical incidents must also take into consideration transportation, storage, use and waste disposal of chemicals. In 1999, more than four billion tonnes of hazardous chemicals were moved around the world and fertilizers, weed killers and insecticides are spread in huge quantities on agricultural lands. Given the current scale of production and use of chemicals, it is not surprising that the potential for chemical incidents is important. During the twentieth century, the frequency of chemical incidents involving at least three deaths, 20 injuries or an estimated cost of damages above US$ 7 million in Organisation for Economic Co-operation and Development (OECD) member countries increased by at least an order of magnitude.[3] Table 1 lists both recent and current chemical incidents together with their outcomes, including the Bhopal and the Seveso incidents, whose consequences are still being monitored. Many of these chemical incidents will be detailed in this document as case-studies.

Whereas the frequency of chemical incidents increased, the severity of the impacts of industrial disasters decreased during the twentieth century. This reduced severity is due to an improved ability to manage chemical emergencies in many developed nations, thanks to the development of basic management elements, such as the creation of general labelling and safety standards, the existence of an emergency plan, better communications with the various stakeholders involved, training sessions and exercises and the creation of mechanisms aimed at learning from the mistakes made during past experiences. However, there is still a persistent need for better management of chemical incidents. Common weaknesses include the existence of fragmented roles and unclear responsibilities among the various chemical emergency responders.

Chemical incidents cause anxiety in the public and can lead to a loss of confidence in the ability of national and local governments to deal with public health issues. Although large incidents are thankfully rare, the overall human impact between 1970 and 1998 of all reported chemical incidents worldwide ranged between approximately 13 000 deaths and 100 000 injuries or illnesses to the evacuation of three million people. These estimates of deaths, injuries and illnesses do not fully take into account the delayed health effects caused by chemical incidents, such as cancers or birth defects. The negative impacts of a chemical incident on the local economy can also be extremely high and may include disruption of agriculture, loss of jobs, long-term evacuation of the area, rising costs for health care, litigation and rehabilitation. Finally, as exemplified by the situation in Bhopal more than 20 years after the incident (section 6), chemical incidents can result in extensive damage to the environment, which might take years to remedy and hence might continue to pose a significant public health hazard.

To minimize these negative impacts, and because chemical incidents often involve acute releases and health risks with a very dynamic time course (as a result of changing conditions, e.g. weather, exposure routes, secondary emissions) it is critical to ensure that the authorities, emergency responders and (plant) operators work together in a rapid, comprehensive and effective response to chemical incidents.

[1] Chemical Abstracts Service, a Division of the American Chemical Society, 2007.
[2] *Guidance for national and regional policy makers in the public/environmental health roles.* International Programme on Chemical Safety (IPCS) publication, 1999 (http://www.intox.org/databank/documents/supplem/supp/vintox.htm).
[3] Coleman L. 2006. Frequency of man-made disasters in the 20th century. *Journal of Contingencies and Crisis Management*, 14:3–11.

TABLE 1: EXAMPLES OF CHEMICAL INCIDENTS WORLDWIDE.
THESE EXAMPLES ARE DESCRIBED AS CASE-STUDIES IN THIS DOCUMENT. THE PAGE NUMBER OF THE CASE-STUDY IS GIVEN IN THE RIGHT-HAND COLUMN.

Year	Location	Description of incident	Consequences	Page #
1976	Seveso, Italy	Airborne release of dioxin from an industrial plant	• No immediate human deaths • 3 300 animal deaths • 80 000 animals slaughtered	75
1984	Bhopal, India	Methyl isocyanate (MIC) leak from a tank	• 3800 immediate deaths • 15 000 to 20 000 premature deaths • 500 000 exposed to the gas	*Incident* 2 *20 years later* 82
1984	Mexico City, Mexico	Explosion of liquefied petroleum gas (LPG) terminal	• 500 deaths • 6400 injuries	9
1995	Tokyo, Japan	Deliberate release of a warfare agent	• 12 deaths • 54 critical casualties • Thousands of people affected	35
2000	Enschede, The Netherlands	Explosion of a fireworks factory	• 20 deaths, 562 casualties • Hundreds of houses destroyed • 2000 people evacuated	86
2001	Toulouse, France	Explosion of 300–400 tonnes of ammonium nitrate in a fertilizer facility	• 30 deaths • 2500 casualties • 500 homes uninhabitable	26
2002	Galicia, Spain	Shipwreck of the *Prestige*, causing the release of 77 000 tonnes of fuel	• Estimated clean-up costs of US$ 2.8 billion	22
2002	Jabalpur, India	Mass poisoning due to the use of pesticide containers as kitchen utensils	• Three deaths • At least 10 hospitalizations	51
2003	Baton Rouge, USA	Release of chlorine gas from a facility	• No human deaths	64
2004	Neyshabur, Iran	Train explosion due to mixing of incompatible chemicals	• Hundreds of deaths and casualties among emergency responders and onlookers	28
2005	Songhua River, China	Plant explosion releasing 100 tonnes of pollutants in the Songhua River	• Five deaths • Millions of people without water for several days	41
2005	Bohol, The Philippines	Inadvertent use of an insecticide in the preparation of sweets	• 29 deaths • 104 hospitalizations	47
2005	Hemel Hempstead, England	Three explosions in an oil storage facility (Buncefield depot)	• 43 reported injuries • 2000 persons evacuated	66
2006	Abidjan, Côte d'Ivoire	Dumping of toxic waste in the city of Abidjan	• 10 deaths, thousands made ill	42
2006	Panama	Diethylene glycol in a cough syrup	• At least 100 deaths	53
2007	Angola	Sodium bromide confused with table salt	• At least 460 people ill, most of them children	10
2008	Senegal	Lead from informal battery recycling	• People exposed with many children showing symptoms of lead intoxication	80

1.2 SCOPE AND DEFINITIONS

A chemical incident is the uncontrolled release of a toxic substance, resulting in (potential) harm to public health and the environment.[1] Chemical incidents usually trigger a public health response, including, for example, assessment of exposure and risk and/or provision of advice to authorities and/or the public.

Chemical incidents can have many manifestations, with different initiating events (natural or anthropogenic), incident dynamics, injury types, and necessary public health responses. Therefore, the term "chemical incident" might refer to anthropogenic events such as the explosion of a factory which stores or uses chemicals, contamination of the food or water supply with a chemical, an oil spill, a leak in a storage unit during transportation or an outbreak of disease that is (likely to be) associated with chemical exposure. Chemical incidents can also arise from natural sources

[1] *Glossary of the Health Protection Agency*, UK (http://www.hpa.org.uk)

such as volcanoes, earthquakes and forest fires. Natural disasters may disrupt chemical containment systems and cause secondary anthropogenic chemical incidents (e.g. tank rupture after flooding). Whatever the cause, the chemical incident might be discovered by either knowledge of the contamination or knowledge of health conditions likely to have a common chemical etiology, including disease outbreaks.

As shown by the toxic waste crisis in the Côte d'Ivoire (see page 42), chemical incidents can happen anywhere and at any time, even if there are no chemical facilities in the area. Although most chemical incidents are small and involve few people, the accumulated consequences may be just as serious as those of large incidents in terms of illness, death, environmental and economic damage, and the anxiety they generate for the public, emergency services personnel and employees. Small incidents are often less visible and generate less publicity. However, the health response should be as serious and professional as if it were a big event. In addition, small incidents are occasions to verify the completeness and feasibility of the preparedness plans and for responders to sharpen their skills.

BOX 1: DEFINITIONS

DISASTER
Situation in which substantial numbers of people are exposed to hazards to which they are vulnerable, with resulting injury and loss of life, often combined with damage to property and livelihoods.

EMERGENCY
Outgrowth of a disaster, in which the affected communities' capability to react has been overwhelmed and where rapid and effective action is required to prevent further loss of life and livelihood.

INCIDENT
Situation in which people are potentially exposed to hazards to which they are vulnerable, with resulting public concern and the possibility of immediate or delayed risks to health.

Wisner B, Adams J (eds). *Environmental health in emergencies and disasters, a practical guide.* Geneva, World Health Organization, 2002.

The following subsections aim to provide an overview of the main injury mechanisms, incident types, the disaster cycle and disaster typology as a reference for the remainder of the publication.

1.2.1 Injury mechanisms

Chemical incidents can cause injury through four basic injury mechanisms: fire, explosion, toxicity and the experience of traumatic events. These injury mechanisms may appear to be quite distinct, but in reality are strongly interrelated.

- Fire produces injuries through heat and exposure to toxic substances (including combustion products). A secondary effect of a fire may be an explosion or tank failure due to heating of tanks holding chemicals. Every major fire can be considered a chemical incident.
- An explosion produces traumatic (mechanical) injuries through the resulting shockwave (blast), fragments and projectiles. As a secondary effect an explosion may result in a fire or loss of containment resulting in release of and exposure to toxic chemicals (e.g. through penetration of an adjacent tank by fragments: so-called domino effects).
- Toxicity may result when humans come into contact with a chemical released from its containment, be it from storage or transport, or as reaction or combustion products. Toxicity can cause harm by a wide array of toxic mechanisms ranging from chemical burns to asphyxiation and neurotoxicity.[1,2]
- Mental health effects, the final type of "injury" are not only determined by exposure to the chemical, fire or explosion but also by "exposure to the event" itself. Severe incidents have the potential to disrupt the lives of victims through injury, loss of relatives, property or employment and societal disruption. A substantial proportion of victims of major incidents have been shown to experience long-lasting mental health problems.[3]

[1] Goldfrank et al, Goldfrank's Toxicologic Emergencies – 8th Ed. (2006), The McGraw-Hill Companies, Inc, New York, 2006.
[2] Dart, RC (ed.) *Medical toxicology*, 3rd ed., Philadelphia, Lippincott Williams & Williams, 2004 (www.LWW.com).
[3] Health Council of the Netherlands. *The medium and long-term health impact of disasters.* The Hague, Gezondheidsraad, 2007 (Report 2006/18E) (http://www.gr.nl/pdf.php?ID=1487&p=1).

While it is recognized that all the above-mentioned mechanisms are highly relevant, the focus for the remainder of this manual will be on toxicity. Some mental health aspects will be addressed as well.

1.2.2 Examples of incident scenarios

This section will introduce seven different manifestations of a chemical incident to facilitate framing their public health management. The incident types differ in initiating event, dynamics (time course), and the first risk assessment and public health actions to be taken. This incident typology is by no means absolute, and is only provided as a tool to identify incidents and primary activities during the response. Combinations of incident types are possible. Common characteristics such as the potential to spread across administrative boundaries and legal implications are not detailed here.

Incidents can occur indoors and outdoors. The focus of the descriptions below will be on outdoor releases, because these are often larger and have the potential to affect more individuals than indoor releases. The consequences of outdoor releases can extend to the indoor environment, and may result in exposures within buildings and subsequent risks to health.

The following types of incident scenario will be described in terms of the typical course of the incident, and primary risk assessment and public health actions.

1. Sudden evident outdoor release of gas or vapour

Typical course of the incident

A gas or vapour cloud with an acute time course, possibly after evaporation from a pool of liquid. Inhalation exposure is possible far downwind of the release site and there is a possibility of significant skin contact on-site. The incident scene is accessible soon after the release has been terminated because the vapour or gas cloud has moved downwind and been dispersed (unless a pool is still present). Often rapid reports of odour or respiratory and eye irritation will be received, but depending on the nature of the chemical, health effects can be delayed for hours to days.

Risk assessment

In many cases only one or two chemicals are involved rather than a completely unknown mixture of substances. Atmospheric conditions largely determine the dispersion; gas pockets are possible, particularly after release of a heavy gas. The population at risk can usually be determined quite rapidly from complaints and dispersion modelling. The first environmental monitoring results will rarely come in before 30–45 minutes following the chemical release. The possibility of delayed health effects should be considered. The likelihood of secondary contamination outside the incident scene is usually low.

Public health key points

Usually advice to go indoors, shut all doors and windows, disengage mechanical ventilation (shelter-in-place advice) is appropriate for the population downwind of the incident. Building characteristics determine the protectiveness and safe shelter duration which is the length of time for which those at risk of chemical exposure should remain in a safe shelter. The alert to shelter-in-place should include public alert systems (sirens) supported by continuous and consistent communication through multiple channels including radio, television, websites and telephone transmissions. If the wind direction is expected to shift, preventive evacuation can be considered. After the toxic cloud has passed, there are usually few or no restrictions on outdoor activities.

Typical example

Release of methyl isocyanate in Bhopal, 1984 (page 2).

2. Sudden evident outdoor release of an aerosol

Typical course of the incident

A sudden emission of liquid or solid aerosol occurs into the air outdoors and/or indoors; the material deposits on soil and infrastructure, where it remains until it is removed either intentionally (e.g. in a clean-up) or by natural mechanisms (e.g. wind or rain). The contaminated area outdoors can range over kilometres, depending on the type of the event (e.g. explosion), characteristics of the aerosol and environmental conditions. Inhalation exposure usually occurs during and shortly after the emission; dusty material (e.g. asbestos) can be re suspended by wind, vehicles, and other mechanisms. Primary exposure via the oral and skin routes is possible on-scene and wherever (and as long as) deposited material persists.

Risk assessment

Usually information about the composition of the emitted material and the particle size distribution is unavailable in the acute stage. Quantitative assessment of exposure with modelling and monitoring is very difficult; usually exposure is assessed by visual determination in the contaminated area. Children living or spending time near to the site of the accident may be at relatively greater risk because they are more vulnerable to exposure (e.g. they spend more time outside playing and hand-to-mouth behaviour increases ingestion of settled dust); in agricultural areas, contamination of crops and grassland may be an issue.

Public health key points

Information about restrictions on access to the outdoor area and clean-up is critical, particularly as long as the health risk has not been determined. Compliance with health advice is generally high in areas where contamination is visible, the occurrence of acute effects is recognized widely, and concern about delayed effects (e.g. for carcinogenic substances) is communicated clearly.

Typical example

Release of dioxin in Seveso, Italy, 1976 (page 75).

3. Sudden evident release to contact media other than air

Typical course of the incident

An immediately detected release of a substance occurs in water, soil or directly into food (e.g. during food processing) or other media (e.g. sediments or consumer products). It is often easier to avoid primary human contact with the chemical for this scenario than it is to avoid contact with airborne releases because it is often possible to discontinue exposure through these media, at least for a short time. Secondary contamination of food, drinking-water and consumer products can occur as well following release of a chemical to surface water or soil. Other secondary consequences may be adverse impacts on wildlife, including fish, birds and whole ecosystems. The time taken to respond to incidents of this type is usually a matter of hours, rather than minutes as for types 1 and 2.

Risk assessment

The possible pathways for human exposure and the resulting health risk depend on the physicochemical properties of the substance and its eventual environmental fate. Volatile substances may evaporate quickly and be detected by their odour or taste. Chemicals with low vapour pressure will partition primarily between water and soil, or other substrates rich in organic matter, depending upon their structure and solubility in water.

Public health key points

Warning the public to take immediate action is rarely required, unless information needs to be provided about odour. The focus is on the environmental incident. At some stage, nearby residents will ask for information about the association between e.g. fish mortality and effects on human health. A well-conducted exposure study focusing on all possible routes of exposure and subsequent risk assessment will be very helpful.

Typical example

Benzene release in the Songhua river, China, 2005 (page 41).

4. Fire in a large building

Typical course of the incident

This type of incident includes fires in residential and shopping areas, warehouses, fixed chemical storage and production sites, tunnels and underground railways. Combustion products are determined by the burning material and the type of fire (pyrolysis, poorly or well oxygenated fires). The heat of combustion influences the air dispersion of the toxic smoke. Victims with serious injuries are mostly found inside or near such burning structures,. Secondary explosions may occur. Emergency response and environment personnel are at risk of exposure through contaminated runoff. Populations downwind of a release point are at particular risk of exposure and subsequent immediate and delayed health consequences. The size and constituency of this population at risk will determine the scope of the response action.

Risk assessment

The characteristics of the affected building can provide a rough indication of the materials on fire; identification of the material on fire has proven very difficult for warehouses in which the inventory of stored products is varied and may change over time. The initial risk assessment is based on smoke and combustion products. Exposure modelling is complex; visual observation and environmental monitoring often provide more useful estimates of exposure. It is often impossible to make a quantitative risk assessment in the acute stage. Deposited material may cause secondary contamination identical to that seen in type 2 incidents.

Public health key points

The safety of emergency responders is crucial, particularly when explosions or contamination of fire-extinguishing runoff are possible. Since risk assessment is difficult, a precautionary approach is often used in providing advice on sheltering and use restrictions. Evacuation of the building's residents and of neighbours with high exposure to smoke is advisable, and may need to be continued for some days.

Typical example

Fire at the Buncefield oil depot, England, 2005 (page 66).

5. Explosion

Typical course of the incident

In many cases explosions have a forewarning period. The affected area is roughly circular around the explosion site, although high buildings may act as a shield. Explosions cause structural damage to buildings (resulting in entrapment or dust exposure after collapse), fragments, projectiles and glass splinters. In some cases a fireball or gas cloud explosion (with distant ignition) occurs.

Risk assessment

The major types of injury are burns from thermal radiation and traumatic (mechanical) injury due to the blast (gas filled organs and rupture of the tympanic membrane), fragments and projectiles. These risks are relatively well established. Toxicity is usually due to combustion products from secondary fires or (resuspended) material on the soil or infrastructure.

Public health key points

In case of a forewarned explosion there may be time to provide instructions on risk reduction to the at-risk population. In all cases the safety of emergency responders is a primary concern: for a threat of explosion or after an explosion (for example, owing to building instability and collapse). Experienced urban search and rescue teams may be necessary. Access to the affected area may be problematic if there is debris on access roads. Long-term shelter and provision of basic essentials may be necessary for those who have lost their homes.

Typical example

Explosions and fire at the PEMEX Liquid Petroleum Gas Terminal, Mexico 1984 (page 9).

6. Disease outbreak

Typical course of the incident

In this case it is not the release of the chemical that is detected, but an increase in the number of people with a more or less consistent syndrome of signs and symptoms. Detection is usually through surveillance systems and/or watchful clinicians, and usually takes days to weeks or months depending on the specificity of the clinical syndrome and the geographical spread of the patients. The common source may remain obscure for a long time, and all exposure routes and contact media should be considered. Mass psychogenic illness and (bio)terrorist attacks should also be considered as common causes.

CASE STUDY 2: EXPLOSIONS AND FIRE AT PEMEX LIQUID PETROLEUM GAS TERMINAL – MEXICO

On the morning of 19 November 1984 a major fire and a series of catastrophic explosions occurred at the PEMEX Liquid Petroleum Gas (LPG) Terminal at San Juan Ixhuatepec, Mexico City. The incident led to the deaths of 500 people; 6400 were injured and the terminal was destroyed.

The plant was being filled from a refinery 400 km away. Two large spheres and 48 cylindrical vessels were filled to 90% capacity and four smaller spheres to 50% full. An 8-inch pipe between a sphere and a series of cylinders ruptured. This caused a drop in pressure that was noticed in the control room, but the operators could not identify its cause. The release of LPG continued for about 5–10 minutes when the gas cloud (estimated at 200 m x 150 m x 2 m high) was ignited by a flare stack. This caused a violent ground shock, and a number of ground fires occurred. Workers at the plant then tried to deal with the release by taking various courses of action. At a late stage somebody pressed the emergency shut-down button.

About 15 minutes after the initial release the first boiling liquid expanding vapour explosion (BLEVE) occurred. For the next hour and a half there followed a series of BLEVEs as the LPG vessels violently exploded. LPG was said to rain down and surfaces covered in the liquid were set alight. The arrival of emergency services was hindered by the traffic chaos, which built up when residents sought to escape from the area.

KEY POINTS

- Explosion and fire can be devastating effects of chemical emergencies.
- The total destruction of the terminal occurred because there was a failure of the overall basis for ensuring safety which included the layout of the plant and emergency isolation features.
- The terminal's fire water system was disabled in the initial blast. Also the water spray systems were inadequate.
- The installation of a more effective gas detection and emergency isolation system could have averted the incident. The plant had no gas detection system and therefore when the emergency isolation was initiated it was probably too late.
- The site emergency plan was inadequate to allow rapid entry of emergency services to help control the accident.

Risk assessment

The approach to risk assessment for this type of incident involves strengthening disease surveillance (including developing a case definition), assessment and verification of clinical presentation, and the search for the chemical hazard and a possible common source of exposure (primary and/or secondary contamination), using toxicological and epidemiological tools. Possible chemical hazards, sources and reported effects are investigated simultaneously. After identification of the hazard and source, a detailed exposure assessment should be made to verify the acute effects and predict possible delayed or residual effects and the populations likely to be affected.

Public health key points

Key points are coordination of information, investigations and communication. Most outbreaks will enter the public health system as a suspected outbreak of an infectious disease. A well coordinated cooperation between chemical and infectious disease experts may prevent loss of time in identifying outbreaks with a chemical etiology.

Typical example

Mass endosulfan poisoning, Jabalpur District, India, 2002 (page 51); bromide poisoning in Angola, 2007 (page 10).

7. Silent releases

Typical course of the incident

In the case of silent releases, the release of the chemical into the contact medium is not detected (or no action has been taken) until after the release, but before it has been detected as a disease outbreak. This can happen when the occurrence of an incident is brought out into the open after some time, or when a release is more serious than anticipated at the time of the initial release.

CASE STUDY 3: DISEASE OUTBREAK OF UNKNOWN ETIOLOGY – ANGOLA

In October 2007, a disease outbreak of unknown etiology appeared near Luanda, Angola: by the end of the outbreak in December 2007, 458 cases had been reported. Initially suspected to be infectious, symptoms suggested a toxic etiology and included tiredness, blurred vision, dizziness, weakness and difficulties in speaking and walking.

At the request of the Angolan Ministry of Health (MINSA), the World Health Organization provided technical assistance to identify the cause of the outbreak. Activities included (i) clinical, including neurological examinations; (ii) strengthening surveillance (development of a case definition); (iii) (toxicological) analysis of human and environmental samples; and (iv) a case–control study to detect exposure patterns. Extensive toxicological tests revealed the presence of very high serum levels of bromide (up to 2700 mg/l). Environmental and food samples revealed that table salt contained at least 80% sodium bromide, the causative agent.

Following these findings, public health actions were immediately initiated to control the outbreak, including awareness raising, salt replacement and provision of treatment advice to hospitals and health care facilities.

This incident demonstrates the need to have effective chemical safety plans in place, including building capacities to deal with chemical poisonings that initially might appear as diseases of unknown etiology, especially in developing countries that introduce new technologies. While new industries are being introduced as part of their development process, the general population and workforce are vulnerable to exposure and health effects of chemicals because of poor chemical legislation and regulation, and its inefficient implementation and control, as well as poverty, lack of public awareness of the health effects of chemicals, and lack of capacities, trained staff and infrastructure.

KEY POINTS

- Disease outbreaks of unknown etiology are often reported as suspected outbreaks of infectious disease.
- Coordinated cooperation between chemical experts and infectious disease experts may prevent loss of time in identifying outbreaks of chemical etiology.
- Identification of the cause of a disease outbreak of potential chemical etiology involves multiple disciplines, including (clinical) toxicology, environmental epidemiology and environmental sciences.
- In the case that expertise is lacking, international organizations can be called upon to provide technical assistance.

Risk assessment

The first steps are verification of the chemical, an analysis of all possible exposure pathways and populations, and a quantitative risk assessment with focus on delayed or residual effects.

Public health key points

This type of incident may be a grey area between response to a chemical incident and "regular" environmental health provision. Health investigations should establish a clear link between observed and anticipated delayed health effects and exposure, including the development of case definitions. One of the public health challenges in this scenario (as in other scenarios) is that people who know about or have been close to the event, but have NOT been exposed, may attribute signs and symptoms related to another disease to the incident.

Incident types 1–5 are typically localized: there is an incident scene. In addition to other common traits, public health management of events with an incident scene may include concerns about health risks posed to emergency response personnel. The detection and development of incidents of types 6 and 7 is typically much more diffuse in time, place and person.

1.2.3 The disaster management cycle

The "disaster management cycle" illustrates the continuous process by which governments, businesses and civil society plan for and reduce the impact of incidents by acting at different stages of an incident's life-cycle. The nature of activities that can be undertaken to reach the goal of impact reduction varies with the stage of this cycle. The six stages of the disaster cycle will be introduced briefly (Figure 1).

The first line of defence against adverse consequences of chemical incidents is to prevent their occurrence and to limit their impact if they do occur. **Prevention** is aimed at reducing the likelihood of an incident occurring and includes all technical and organizational measures taken to reduce the severity of any incident that might occur and to ensure that its impact is reduced to a minimum and that it does not become a major event or disaster.

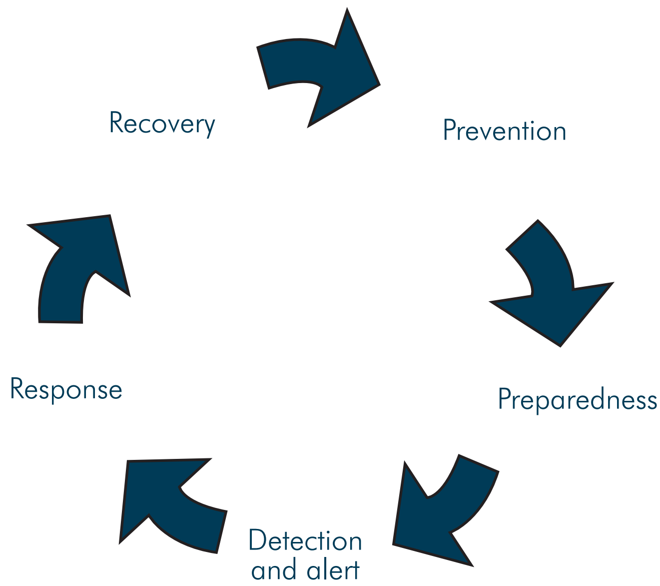
Despite the best efforts to eliminate risks and reduce the likelihood of their occurrence, some residual risk will remain which can materialize in an incident. This residual risk should form the basis for subsequent planning and preparedness. The time taken during an incident to locate equipment and infrastructure, coordinate the actions of the various stakeholders, establish links between agencies and emergency services, establish a response plan and gather general information about the pollutant(s) and the facility responsible for the incident will be time lost towards minimizing the extent and consequences of a chemical incident. Hence, these tasks should be accomplished prior to the incident, in order to ensure that immediate efforts can readily be focused on the response to the incident. Therefore the incident response system should be designed, the roles, responsibilities and competencies attributed, personnel selected, trained and exercised, in the **planning and preparedness** stage.

Incident **detection and alert** is a continuous activity undertaken to pick up signals that a chemical incident has occurred, and to ensure rapid alert for an appropriate and timely response.

When an incident takes place, the operator, authorities and the public initiate the incident **response** to terminate the incident and mitigate the consequences.

After the incident has been terminated the **recovery** may take years of clean-up, health monitoring, evaluation and other activities that are aimed at restoring the situation to how it **was before the incident and contributing to prevention of recurrence**.

FIGURE 1: STAGES OF THE DISASTER MANAGEMENT CYCLE



An example might explain the different stages of the disaster cycle. When considering the prevention and mitigation of incidents arising from a large ammonia-filled cooling installation close to a residential area, the following activities fit to each of the stages of the disaster management cycle:

- A **preventive** approach could be to replace the ammonia with a less toxic and flammable chemical, reduce the amount of stored ammonia, build in redundancy of technical safety (partition the ammonia into smaller vessels, strengthen the vessels and pipes) and/or relocate the facility to somewhere where a release would not harm the public and the environment or create a distance between the installation and nearby residents.
- **Preparation** would include development of release scenarios and planning the possible best response, providing information and training for the public, installation of a public warning system, training and equipping responders to deal with loss of containment.
- **Detection and alert** would include installation of gas detection systems (from operator controls to fence-line monitoring), development of an effective system for alert and scaling up the incident response and actually using these to monitor for a release.

- **Response** would be the termination and mitigation of an actual loss of containment and its health consequences.
- **Recovery** includes activities such as health assessment, clean-up and investigation of the root cause to prevent recurrence.

The remainder of this manual is structured to follow the stages of the disaster management cycle.

1.2.4 A chemical incident management structure

To manage and co-ordinate the widely differing activities undertaken by the many actors involved at the different stages of the disaster cycle, an organizational structure that includes public health professionals is recommended at the various administrative levels (e.g. national, provincial, and/or local levels). Possible actors are the operators (e.g. fixed facility, transport), authorities (national, local), emergency services, employees and the public.

This organization might be hosted by whichever agency is considered most suitable for a given country. Alternatively, management of chemical incidents could be the responsibility of a network of government departments and/or institutes at the national, provincial and local levels. Such an organization would include ministries responsible for important elements of prevention, preparedness, and response to chemical incidents, such as the ministries of health, labour, environment, transport, civil protection and security.

The stages of the disaster cycle determine which disciplines are likely to play a predominant role. To ensure comprehensive and consistent prevention and mitigation of chemical incidents, national governments are advised to identify a responsible official, governmental department or interdisciplinary standing committee to assume responsibility for coordination and management of chemical incidents at the national level. The responsible organization would in turn be responsible for identifying other governmental departments, national bodies and experts to assist in the coordination of activities associated with managing chemical incidents.

Regardless of its structure, membership, and level within the government, the organization would have the responsibility to coordinate and to develop a policy to prevent, prepare for and protect the citizens of the country against chemical incidents. In addition, it would be responsible for establishing multidisciplinary teams or coordinating centres at subnational administrative levels to conduct many of the local tasks involved in the prevention and management of chemical events. The organization should provide leadership and motivate all the other agencies that will be involved in responding to a chemical incident to fulfil their roles and responsibilities. In addition, the organization must ensure that resources (financial, personnel and training) are available to local networks, be they public health, emergency response or environmental networks.

On a national level, the main tasks of the organization are to develop:

- a national chemical emergency coordinating structure, including appropriately trained staff with the right knowledge and skills for dealing with each of the stages of the disaster cycle;
- a Chemical Incident Response Plan (including public health involvement);
- the necessary policy, legislation and enforcement for all stages of the disaster cycle;
- databases on chemicals, sites, transport routes and expertise;
- mechanism for interagency communication and public communication;
- emergency response guidelines, including environmental protection guidelines;
- incident exercises, training, and audits;
- preventive measures;
- national Chemical Incident Surveillance;
- organization of independent investigation of chemical incidents.

1.3 CORE PUBLIC HEALTH FUNCTIONS

Public health has a key role to play at every stage of the disaster management cycle for chemical incidents. For the functions of risk assessment and communication, the public health role is particularly evident. These two activities will be introduced briefly below, and will serve as a connecting thread throughout this manual.

1.3.1 Risk assessment

Assessment of risk to human health is the core public health function in the prevention and management of chemical incidents. An assessment of risk to human health is the process to characterize the nature and probability of adverse effects on the health of humans who may be exposed to chemicals in contaminated environmental media, now or in the future. Risk assessment is considered to be a four-step process, as outlined in Figure 2 below:

Step 1 – hazard identification is to identify the types of adverse effects on health that can be caused by exposure to the agent in question, and to characterize the quality and weight of evidence supporting this identification. Therefore, this process reflects the inherent toxicology of the chemical(s) in question without predicting the likelihood of an effect.

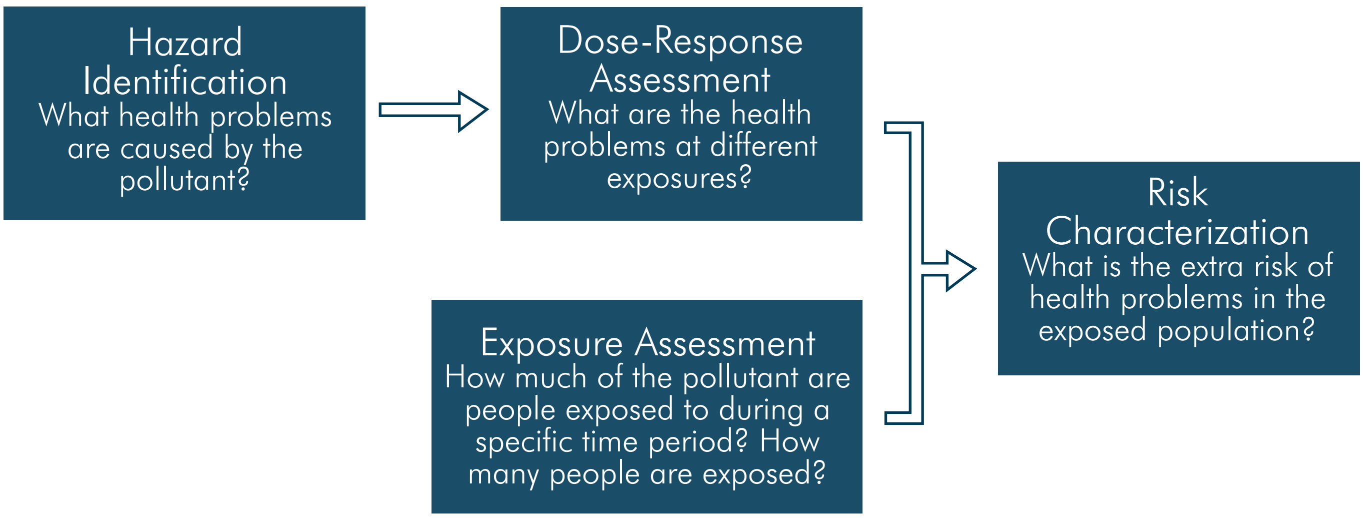
Step 2 – dose–response assessment is to document the relationship between exposure or dose and toxic effect. For emergency response purposes, this is often performed by developing emergency response guidelines for rapid risk assessment.

Step 3 – exposure assessment is to calculate a numerical estimate of exposure or dose relevant for the exposure scenario in question.

Step 4 – risk characterization is to summarize and integrate information from the preceding steps in the risk assessment to synthesize an overall conclusion about risk. For chemical incidents, it may be useful to distinguish between the risks of acute and delayed health effects.

Risk assessment will be discussed in detail in chapter 3 (planning and preparedness). In the other chapters, the public health contribution to risk assessment will be discussed briefly within the particular context of each chapter.

FIGURE 2: THE 4 STEP RISK ASSESSMENT PROCESS[a]



[a] Text and figure adapted from the US Environmental Protection Agency (http://www.epa.gov/risk/health-risk.htm).

This document describes five forms of risk assessment that are common to activities conducted at various stages in the public health management of chemical incidents. As summarized in Table 2, each of these forms is referred to with a specific term that is intended to be descriptive and to facilitate understanding the goal of the assessment. To further aid in describing their particular purposes, the five forms of risk assessment are also distinguished by the component of the disaster cycle in which they are practised.

1.3.2 Communication

Communication with the public is another core function in which public health can play a crucial role: public health professionals often have valuable experience in communicating about health risks with the public. For the purpose of this manual a distinction will be made between risk communication and crisis communication.

Risk communication refers to communication about possible incident scenarios, information about possible protective actions and public involvement in siting and licensing of facilities where chemicals are produced, used or stored before an incident occurs.

Crisis communication refers to communication about actual risk and appropriate risk-reducing (avoiding) behaviour *during* an incident.

Good risk communication opens communication channels, builds trust and thereby lays the foundations for effective crisis communication. The cornerstones of effective risk and crisis communication are speed, openness, transparency and continuity of communication. In each of the following chapters some information will be provided about possible communication strategies and subjects.

TABLE 2: SUMMARY OF TYPES OF HEALTH ASSESSMENTS DESCRIBED IN THIS MANUAL

Name	Stage of disaster cycle	Purpose	Section
Health impact assessment	Prevention and preparedness	To estimate potential risks associated with various hypothetical release scenarios and the accompanying options for managing the chemical incident.	2.2 and 3.3
Health risk assessment	Response	To predict health outcomes associated with a known or suspected chemical release or existing condition, using estimates of actual exposure and existing knowledge on exposure/dose-response. Used to make decisions about need for further response and recovery actions.	3.3 and 5.3
Best outcome assessment	Response	To determine the best course of action during or in the immediate aftermath of a chemical incident. May be an application of health impact assessment to incident-specific conditions. Action-oriented.	5.5
Rapid assessment	Response	To provide a screening level analysis of risk during or in the immediate aftermath of a chemical incident and to inform decisions about next steps in response. Uses exposure guidelines as rapid indicator of risk. Often conducted prior to best outcome assessments and health risk assessments.	5.1 and 5.3
Health outcome assessment	Response and Recovery	Actual measurement of the health outcomes of a chemical incident, often conducted as an epidemiological study. Can be initiated in the response or recovery stages. Necessarily retrospective.	6.2

2 PREVENTION

Prevention is aimed at reducing the likelihood of chemical incidents occurring and reducing their severity if they do occur. Proactive measures intended to eliminate structural causes of incidents are an important element of prevention. When it is not possible to eliminate the potential cause of a chemical incident completely, prevention focuses on reducing the likelihood of a chemical incident and reducing the vulnerability (increasing the resilience) of exposed populations in the event of a chemical incident.

This chapter will describe some concepts of risk-based design, policy development and implementation and scenario analysis. Technical and chemical engineers usually play a dominant role at this stage, whereas historically there has been a modest role for public health. From a technical perspective the prevention stage is concerned with failure rates of installations (or their components), physical effect scenarios and modelling of consequences in a highly legislated environment. Legal considerations include land-use planning, siting and licensing of installations and transport routes. The most important public health input at these stages includes assessment of the health impact of possible release scenarios and risk communication.

2.1 PROTECTION LAYERS

Technical engineers think of the various measures to prevent and mitigate chemical incidents as "lines of defence" (LOD) or "layers of protection" (LOPs). This concept is useful in itself, and some insight by public health professionals into the most common applications of LOP may greatly facilitate communication with the engineering community. A conceptual model of LOPs is illustrated in Figure 3.

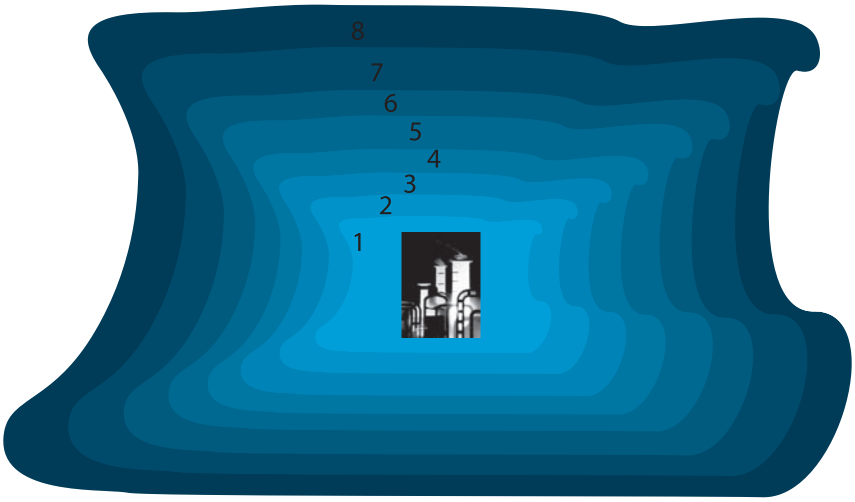
Two types of LOP are typically considered. First, protection layers that serve to prevent an initiating event from developing into an incident are referred to as prevention LOPs. Second, protection layers that reduce the consequences of an incident once it occurs are termed mitigation LOPs.

The diagram in Figure 3 is useful for understanding the concept of LOP, but is not practical for analysing possible release scenarios and the influence of protection and mitigation LOPs. For such analyses the so-called bow-tie diagram is used (Figure 4). The concept of this diagram will be illustrated with an example.

Consider a storage vessel with hydrazine (a toxic and explosive volatile liquid chemical) as an example. A number of initiating events can lead to a release, if all preventive LOPs fail. Possible initiating events are (referring to the numbers in the Figure):

1. Collision with road tanker delivering hydrazine. LOP 1a could be a fence to prevent collision of the tanker with the truck. LOP 1b could be reinforcement of the walls of the storage vessel. LOP 1c could be

FIGURE 3: LAYERS OF PROTECTION (LOP) AGAINST A CHEMICAL INCIDENT[a]



1 Process Design

2 Basic Controls, Process Alarms, and Operator Supervision

3 Critical Alarms, Operator Supervision and Manual Intervention

4 Automatic Action SIS or ESD

5 Physical Protection (Relief Devices)

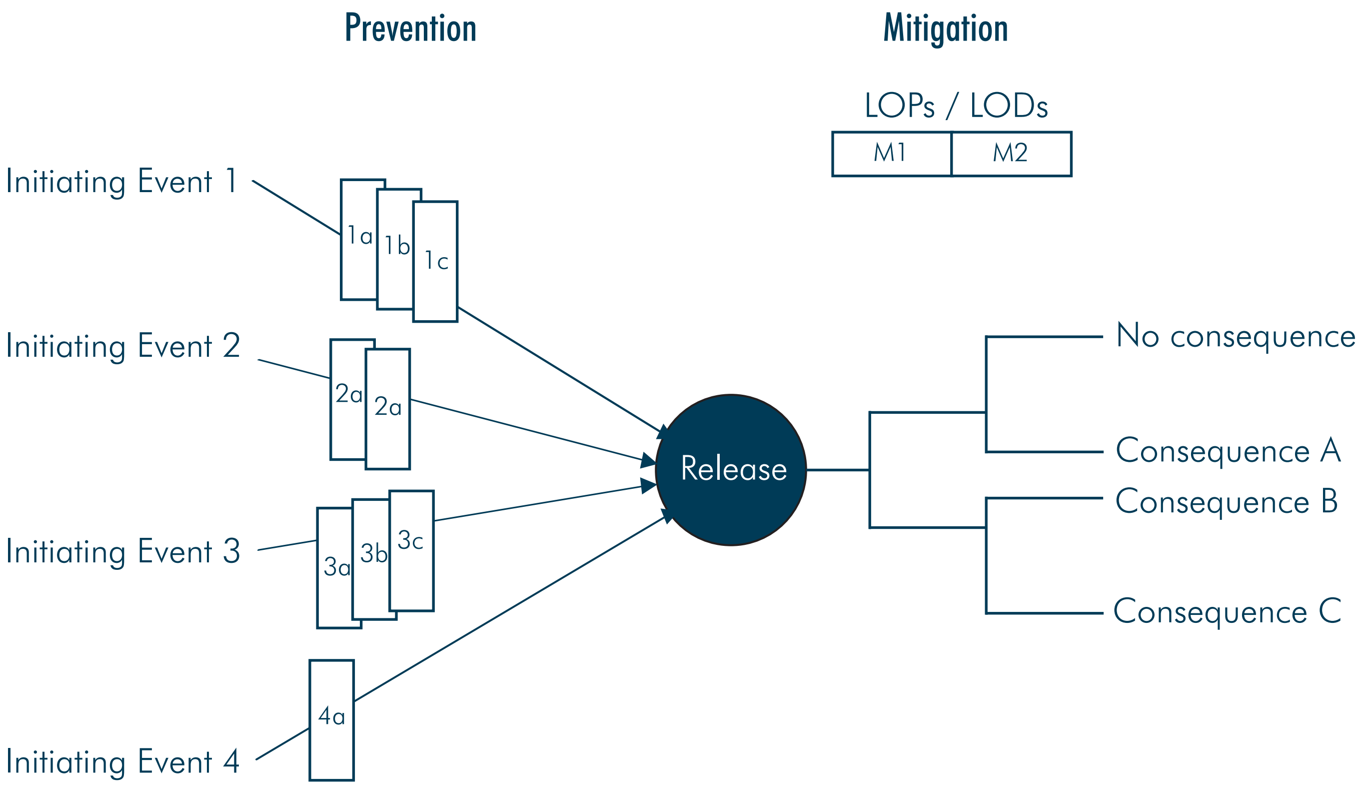
6 Physical Protection (Dikes)

7 Plant Emergency Response

8 Community Emergency Response

[a] Adapted from graphic on the website of ABS consulting (http://www.absconsulting.com/svc_opRisk_LOPA.html).

FIGURE 4: A BOW-TIE DIAGRAM TO ANALYSE RELEASE SCENARIOS AND THE EFFECT OF LOPS



[a] Health and Safety Executive (2004). 'Lines of Defence/Layers of Protection Analysis in the COMAH Context'. Amey Vectra Report 300-2017-R02. UK

mandatory supervision by site personnel when the tanker manoeuvres to the storage. If all preventive LOPs fail, a tank breach will occur resulting in a release of the chemical.

2. Rupture of a valve by the road tanker. The fence introduced earlier as LOP1a would also work to prevent a release resulting from this initiating event.

3. Tanker driver attempts to drive away with filling hose attached. Preventive LOP 3a could be a technical measure that prevents driving until the filling is complete, 3b could be an audible alarm and 3c supervision by the site personnel.

4. Corrosion of the hose. LOP 4a could be a mandatory check of hose integrity before coupling.

Multiple forms of protection at a given layer provide redundancy which is an important feature of prevention. Systematic analysis of vulnerabilities in a process or facility is essential in order to determine the appropriate types of prevention LOPs necessary in a given situation.

If all prevention LOPs fail, a loss of containment and a release may follow. When this happens, mitigation LOPs are intended to minimize emissions, control exposure, and manage potential risk. For the example above:

1. M1 could be a rapid transfer system to neighbouring containers to reduce the amount released, an enclosure around the storage vessel that captures the released hydrazine, followed by application of a foam cover to prevent evaporation of volatile materials.
2. M2 could be a fence-line water spray system to knock down any vapour that might escape, a system to prevent ignition and a fire extinguishing system. These measures have to be in place in case the foam cover proves insufficient.

Analysis of initiating events, prevention LOPs, and mitigation LOPs allows public health authorities and others involved in managing chemical incidents to evaluate the possible scenarios for a chemical release from a facility, or an activity, their possible consequences and possibilities for intervention. The same concept can be applied to food and drinking-water safety, transportation, and other scenarios. Knowledge about the likelihood and magnitude of consequences is useful for the later stages of the disaster cycle including preparedness and response.

The LOP concept and bow-tie tool illustrate that the responsibility for incident prevention rests primarily with the operator, starting at the design of a fixed facility, storage or transportation route. Community incident planning, preparedness and response are literally the last line of defence, required to cover residual risk. As history has shown, zero risk does not exist: risk from technical installations can be minimized but never entirely excluded.

An LOP or equivalent analysis will help to answer questions about stationary sources and transportation such as "How safe is safe enough?" and "How many protection layers are needed?" Analyses of this type will also help to provide clarity and consistency among stakeholders, document the rationale for decisions or risk-reducing measures, and facilitate understanding among public and commercial organizations.

2.2 SCENARIO ANALYSIS AND IMPACT ASSESSMENT

The LOP analysis will also help to identify possible incident scenarios in terms of released chemicals, duration and quantities. This is one starting point for a scenario analysis, an activity aimed to produce a complete overview of possible incident scenarios and their consequences. Other information on possible scenarios can be found in reports of accident investigations. Monitoring all chemical incidents or near incidents in a country, as well as international incidents, is another good way to identify major impacts or risks that should be taken into account. The reccurrence of small incidents linked to a particular chemical or application may serve as an essential warning flag regarding the existence of problems, which if properly addressed could help prevent a major incident.

Scenario analysis only considers the consequences of a release if it occurs, and requires input from engineering, emergency response and health professionals. The engineers' role would be to identify failure mechanisms. Emergency responders can make a realistic estimate of the time required to terminate resulting emissions. Combining this information provides an estimate of quantities and release rates of chemicals, which is the starting point for dispersion modelling. Based on calculated concentrations in all relevant contact media, health professionals can make an exposure assessment and characterize health impact or risk resulting from each of the possible incident scenarios.

The health sector's role starts with determination of all possible exposure pathways resulting from the identified incident scenarios. Human exposure can be via air or from contact with liquid or solid chemicals. Emergency responders may also be exposed when helping contaminated victims. The public can be exposed through ingestion, skin contact or inhalation via a large number of routes. Each of these exposure routes must be evaluated, but, because of the rapid dispersion, the inhalation route must take precedence. For each of the routes, concentrations in contact media must be estimated as well as the possible intensity and duration of exposure to each contact medium. The reader is also referred to section 3.3 and Figure 7 for a clarification of the most important exposure pathways for chemical incidents.

Often toxic impacts or risks are dominated by a limited number of contact media and exposure pathways. Completion of the impact assessment requires information about the exposure/dose-effect (or exposure/dose-response) relationship of the released chemicals. Guidelines have been developed to facilitate assessment of the impact of acute inhalation exposure; these will be discussed in chapter 5. Information on chemical hazard and impact or risk can be found in a number of online databases, listed in section 3.1.2 (Web links 1). Based on the impact assessment it is possible to assess the likely number of casualties and their health care needs for each scenario, as well as the need for other emergency response capacity to deal with the incident. This projected emergency response requirement can be compared with the actually available capacity. Such a comparison might lead to design adjustments or additional requirements for the operator or local authorities to ensure capacity to deal with incidents.

It is crucial that the scenario analysis is inclusive. As demonstrated by the incident in Toulouse, France, described in section 2.4, page 26 policy-makers and local authorities may not fully appreciate all impacts or risks associated with a particular chemical or situation, which could result in an underestimation of chemical risks.

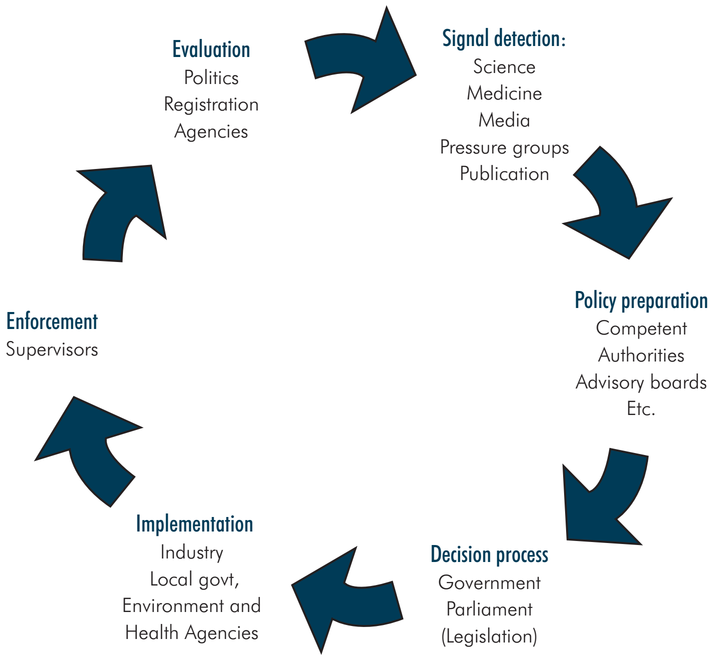
2.3 POLICY, LEGISLATION AND ENFORCEMENT

As part of a government's role in ensuring a certain minimum level of safety and security to its citizens, policy on chemical incident prevention, preparedness, detection, response and recovery should be developed. Such policy is the starting point for the development of laws and regulations and their enforcement. Policy development and implementation is a cyclic process, often represented as the policy cycle (Figure 5).

In many cases, chemical incidents could be avoided by compliance with safety standards, and risk consciousness at all levels of the operator (be it fixed facility or transport).

Instruments for authorities to ensure proper incident prevention are: policy development and strict enforcement of regulations, implementation of international

FIGURE 5: THE CYCLIC PROCESS OF POLICY DEVELOPMENT AND IMPLEMENTATION



agreements, thorough safety inspections, education of the public and a better level of communication between technical professionals and policy-makers.

Developing and enacting legislation that covers chemicals and applications with the potential to harm human health and the environment can help ensure that the hazardous sites and transportation conform to standard safety measures. Legislation is required to effectively minimize the risks associated with chemical sites by planning land-use licensing so that chemical incidents are less likely to occur, and are properly managed when they do occur. Much of the legislation necessary to reduce the probability of the occurrence of an incident, reduce the effects of an incident, and enhance the effectiveness of the response to an incident is likely to have multiple purposes beyond those related to the management of chemical incidents only. Consequently, much of the required legislation may exist already and needs only to be identified, reviewed and revised taking into account chemical events. The following national policies, laws and regulations will help in managing chemical sites.

2.3.1 Land-use planning

Before informed decisions on siting and licensing of chemical installations and transport routes can be made, an overall land-use plan is very helpful. Such a plan can identify areas where chemical installations can be planned at a sufficient distance away from sensitive locations (e.g. drinking-water catchment areas) and vulnerable populations (e.g. schools). A land-use plan provides clarity as to where a licence to operate a facility or build a transport route can be considered, and where the land-use plan precludes such activity. Land-use planning legislation could include the prohibition of site facilities and transportation routes in high risk areas, such as those prone to earthquakes, avalanches or flooding.

Land-use planning is typically managed at the local level. As illustrated by the Bhopal incident described in section 1, page 2 many industries that manufacture, use or store hazardous chemicals are situated in densely populated areas with low per-capita income. Proper land-use planning would help to ensure that hazardous chemical sites are located in less densely populated areas. In addition, land-use planning should take into account the likely fate and transport of chemicals from the site in the event of an incident and possible domino effects, where a failure at one point leads to failures in other parts of the facility.

2.3.2 Licensing of hazardous sites and transport routes

Facilities should not be allowed to produce, store or use hazardous chemicals without the prior and continuing approval of an identified governmental agency. In addition to registration of hazardous waste sites in a database, legislation should require that registered facilities comply with a minimum set of safety standards, such as limitation of container size or provision of secondary containment (risk-based design). The authorities require effective instruments to enforce these standards, e.g. penalties such as fines or tax consequences for past wrongdoings in case of non-compliance.

This legislation could specify licensing that would first of all require that an adequate Safety Management System be in place. Operators of hazardous sites should submit details of the operation, such as current (i.e. not outdated) identity and amount of chemicals on site, as well as procedures for handling, storage and emergency response (e.g. in material safety data sheets (MSDS)); and to prepare a site-specific chemical safety and incident plan that operators should coordinate with local authorities. Operators could be required to perform scenario and risk analyses, including of domino effects on site and from neighbouring facilities.

Local authorities with a site in their jurisdiction should then be required to plan for emergency measures to be taken in the event of a chemical release from the site in accordance with the information given during the licensing stage and the operator's plan. Conversely, the authority's ability to deal with identified incident scenarios might play a role in siting and licensing decisions, and may lead to adjustment of the facility or its surroundings. The operators of a facility might also be required to provide information regarding potential risks linked to their daily activities.

2.3.3 Building regulations

National building regulations provide standards to ensure that buildings are constructed and operated safely. Such standards might cover prevention of damage during earthquakes or maintenance of adequate open space between the buildings, and apply to residential buildings as well as to the facility as part of risk-based design. Standards for sites with chemical operations are likely to be very complex, and therefore a specialized agency may be necessary to develop and enforce these standards by requiring site visits by knowledgeable personnel.

2.3.4 Control of chemical transportation and storage

National legislation requiring the labelling of containers to show chemical contents, the nature of the hazard, and the actions that should be taken in the event of a chemical release help to minimize the consequences of accidental exposures to chemicals in transit. Legislation can also include specification of routes for the transportation of hazardous chemicals. International recommendations regarding transport of hazardous products have been issued by the United Nations.[1]

2.3.5 Labour health and safety

Chemical facilities and transport are operated by plant (or transportation) personnel and contractors. Labour health and safety regulation is required to define minimum levels of training (to reduce human error; also required for contractors), chemical protection and medical surveillance. Subcontracted personnel deserve particular attention, since they often lack the in-depth knowledge, experience and instructions to deal with chemical risks on site.[2]

2.3.6 Establishment of a hazardous sites database

A hazardous site is a site that could present dangers to public health, occupational health and the environment through contamination. Legislation that requires facilities which process or store hazardous chemicals to register with a governmental body provides a mechanism to create and maintain a hazardous sites database. Such legislation should establish criteria for identifying hazardous sites. These criteria may be based on, but are not limited to, specific chemicals, chemical mixtures and/or categories of chemicals, and their potential to cause harm to health and the environment. Many chemical emergency incidents involve non-regulated sites, such as small ammonia installations, warehouses, paint shops, swimming pools, that will be more difficult to include in a database through a legislative mechanism. Some potential ways in which to identify and reference these sites are discussed in section 3.1.1.

[1] United Nations Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. *Recommendations on the Transport of Dangerous Goods, UN Model Regulations*. 15th revised ed. United Nations Publications, 2007.

[2] ILO Convention 170 (http://www.ilo.org/ilolex/cgi-lex/convde.pl?C170)

2.3.7 Control of waste disposal sites

Waste disposal sites should be regulated to ensure that hazardous materials are disposed of in designated sites that have adequate barriers to provide proper containment which will prevent reactions of the hazardous materials. Regulations should cover registration, inspection, control, surveillance, training programmes for workers, and penalties for mismanagement of waste disposal sites. Whenever possible, conversion of the hazardous materials to non-hazardous materials should be preferred to, and take place before, disposal. In addition, legislation is needed to control the illegal dumping of waste.

2.3.8 Control of contaminated environment

While air pollution is a major concern following most major chemical incidents, much of the surrounding land may also be contaminated. Contaminated land could potentially include sources of drinking-water, crops, and foodstuff, as well as infrastructures. A chemical incident might also adversely affect business functions in the area and decrease the value of the facility involved in the incident as well as its surroundings. Regulations will be required that allow for access, inspection, sampling, impounding, disposal, compensation, and imposition of penalties. This is particularly an issue in the recovery phase. As discussed below in section 6, incidents such as that in Bhopal have shown that compensation of affected people for negative outcomes of an incident can be anticipated to be a long-term and very costly process. Compensation could be provided by the polluter, or could be collected from other sources, such as a chemical mismanagement tax.

2.3.9 Emergency planning and response

Emergency planning and response is usually organized at the local (or other subnational) level. A national policy should be developed to set minimum requirements for local emergency planning and response activities. Such policy should address:

- detection, alert and scaling up capabilities of local emergency response;
- command/control, roles and responsibilities for local emergency planning and response;
- national support mechanisms, infrastructure and alerting mechanisms;
- requirements for operators to comply and liaise with local governments;
- training and exercise requirements for key personnel;
- planning the capacity of personnel and equipment for dealing with possible chemical incidents.

A certain level of consistency between local governments' organization, procedures and equipment (notably communication) is a prerequisite for effective mutual aid and national assistance.

As part of the policy on responding to incidents, an organization charged with incident investigation should be considered, to ensure that lessons will be learned from incidents that occur. The mandate of such an organization, most notably the choice of focus on fact finding or fault finding, and its independence will have an impact on the willingness of involved parties to cooperate.

2.3.10 Inspection of hazardous sites and transportation

To help enforce the minimum set of safety standards established by the legislation discussed above, an identified governmental agency should be tasked with conducting inspections of hazardous sites (including storage facilities) and transportation (including loading and unloading). Because inspections cannot examine all safety-related aspects of hazardous activities in great detail, the inspection regimen should focus on the operator's system of management of hazardous chemicals to ensure that all necessary safety elements are in place. All aspects of the safety plan should be inspected, particularly during the initial inspections. If this is not done, there is a risk that the plan will become mere words. Importantly, the inspection agency itself should be subjected to a system of checks to ensure that key elements of an inspection are not missed by overwhelmed or complacent personnel.

CASE STUDY 4: OIL SPILL DUE TO THE SHIPWRECK OF THE PRESTIGE – GALICIA, SPAIN

On 13 November 2002, the Bahamas registered tanker *MV Prestige*, which carried 76 972 tonnes of heavy fuel oil, lost power and control during a storm, while some 30 kilometres off Cabo Finisterre, Spain. In spite of her worsening state, the ship was denied access to port in Spain or Portugal and was towed into the Atlantic. On 19 November, the vessel broke in two and sank some 260 kilometres away from Vigo (Spain). The deep water location of the shipwreck made any rescue very difficult and in the following weeks the incident led to the release of an estimated 63 000 tonnes of highly persistent oil.[a] The coast of Galicia, which is home to some of the most diverse maritime ecosystems in Europe, was heavily contaminated and the local fishing industry was destroyed by the ban subsequently placed on fishing and seafood harvesting. The oil spill also affected the coasts of France as far north as Brittany and the waters of Portugal. Overall, the shipwreck of the Prestige affected 1 900 kilometres of coastlines and is Spain's worst environmental incident.

Major clean-up operations were conducted both offshore and along the coast. The costs of the clean-up operations for the Galicean coast alone have been estimated at US$ 3.8 billion. In spite of intense maritime traffic along the Galicean coast, a clear preparedness plan in readiness for the occurrence of a shipwreck was not available. Therefore, the clean-up was started by several thousands of volunteers without any clear coordination and without any public health information related to the potential toxicity of the oil. This lack of organization led to widespread criticism. In addition, the decision to tow the Prestige out to sea rather than allowing her to enter a port where it may have been easier to minimize the stresses on the vessel was criticized.

The incident of the Prestige prompted the European Union to ban transportation of heavy fuel by single hull tankers into European waters. Financial compensation was given by the insurer of the ship and the International Oil Pollution Compensation Fund 1992, but its amount never compensated for the economic losses generated by the incident.

KEY POINTS

- Regulation of hazardous chemicals should include major transportation routes.
- A chemical emergency preparedness plan should be available to deal with potential incidents such as the Prestige oil spill.
- Environmental incidents often trigger spontaneous help from the local population. Such response can induce widespread chemical contamination if no information is given on how to handle the pollutant safely. The level of chemical contamination should therefore be carefully assessed by environmental and public health professionals and communication to the public should be prioritized.
- Safe construction of chemical transports such as vessels (double hull) and proper maintenance are essential for prevention of chemical incidents.
- Vessels used for the transportation of hazardous chemicals should be subjected to stringent inspection.

[a] Prestige oil spill far worse than thought. New Scientist, 27 August 2003 (http://www.newscientist.com/article.ns?id=dn4100).

2.4 INTERNATIONAL REGULATIONS AND TOOLS

2.4.1 Global agreements

Strategic Approach for the Sound Management of Chemicals (SAICM)

The consumption of chemicals by all industries and modern society's reliance on chemicals for virtually all manufacturing processes make the production of chemicals one of the most globalized sectors of the world economy. The Strategic Approach to International Chemicals Management (SAICM) is a policy framework to promote chemical safety around the world, including many aspects of chemical incident prevention and preparedness. It comprises the Dubai Declaration expressing high-level political commitment to SAICM and an Overarching Policy Strategy which sets out its scope, needs, objectives, financial considerations, underlying principles and approaches and implementation and review arrangements. The Declaration and Strategy are accompanied by a Global Plan of Action that serves as a working tool and guidance document to support implementation of the SAICM.[1]

International Health Regulations 2005 (IHR (2005))

IHR (2005) is a legally binding agreement contributing to international public health security by providing a framework for the coordination of the management of

[1] http://www.chem.unep.ch/saicm/

events that may constitute a public health emergency of international concern (PHEIC), and for strengthening the capacity of all countries to detect, assess, notify and respond to public health threats, including those involving chemicals. According to the IHR (2005) a PHEIC refers to an extraordinary public health event that:

a) constitutes a public health risk to other states through the international spread of disease (or disease precursors such as chemicals in air, water, food or articles); and
b) potentially requires a coordinated international (health) response.

Timely and transparent notification of events combined with a collaborative assessment of the risks by the concerned state and WHO, together with effective risk communication will reduce the potential for international spread of disease and the likelihood of unilateral imposition of trade or travel restrictions by other countries. To meet the requirements of IHR (2005), countries are required to establish a set of core capacities to address all types of potential PHEICs including those that involve chemicals (Annex 1 of the Regulations).[1] Core capacities concerning chemical incidents and emergencies should include:

- a reviewed and, if necessary, revised legislation appropriate for chemical emergency surveillance and response;
- a national chemical emergency coordinating structure, as described in section 1.2.4, to oversee implementation of IHR (2005) concerning chemical events;
- a national surveillance system for chemical events (considering also disease outbreaks of unknown but potential chemical etiology), including ensuring sufficient resources for epidemiological surveillance and assessments;
- a chemical incident and emergency response plan that addresses all health aspects (see also section 3);
- established coordination and collaboration between all relevant stakeholders such as ministries, agencies, industry and others from various sectors;
- a national risk assessment, taking action to reduce risks and prepare for residual risks (see section 3);
- a source for specialist advice on chemical poisonings, including on diagnosis and treatment; and
- adequate supplies for managing victims of larger scale chemical incidents (e.g. decontamination equipment, antidotes, devices) for adequate or sufficient specialist health care facilities.

ILO Convention 174 on the Prevention of Major Industrial Accidents

The purpose of the Convention is the prevention of major accidents in factories and industrial establishments involving hazardous substances, and limiting the consequences of such accidents. It requires employers to set up and maintain a documented system of control of major hazards including emergency plans and safety procedures. The Convention, besides providing for responsibility of employers and rights and duties of workers, also envisages that the provisions it contains should be implemented in consultation with the Workers' and Employers' Organizations.[2]

Other international conventions, such as the Rotterdam[3] and Basel conventions[4] are important for preventing the transfer of hazardous materials (chemicals and waste) to countries that do not have the means to handle them properly. The UN have also provided recommendations on the transport of dangerous goods (UN Recommendations on the Transport of Dangerous Goods[5] and the International Convention for the Prevention of Pollution from Ships (MARPOL Convention)[6] and classification and labelling (Globally Harmonized System for Classification and Labelling of Chemicals, GHS[7]). Such conventions, recommendations and guidelines should be implemented and enforced through national laws.

1 http://www.who.int/csr/ihr/en/

2 http://www.ilo.org
3 http://www.pic.int
4 http://www.basel.int
5 http://www.unece.org
6 http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258
7 http://www.unece.org

2.4.2 Regional agreements

In addition to global agreements and guidelines, countries may have to comply with regional agreements and guidelines. Complete coverage of regional agreements is beyond the scope of this publication. Some examples are provided below.

United Nations Economic Commission for Europe (UNECE) Convention on the Transboundary Effects of Industrial Accidents

The UNECE Convention on the Transboundary Effects of Industrial Accidents[1] aims at protecting human beings and the environment against industrial accidents by preventing such accidents as far as possible, by reducing their frequency and severity and by mitigating their effects. It promotes active international cooperation between the Contracting Parties, before, during and after an industrial accident. The Contracting Parties are 26 UNECE Member States and the European Community.

The Seveso Directive

In Europe, the Seveso accident in 1976 prompted the adoption of legislation aimed at the prevention and control of such accidents. The aim of the Seveso Directive is firstly, to prevent major accidents involving dangerous substances, and secondly, as accidents do continue to occur, to limit their consequences not only for humans (safety and health aspects) but also for the environment (environmental aspects). Both aims should be pursued with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner.

The scope of the Directive deals solely with the presence of dangerous substances in establishments. It covers both industrial "activities" and the storage of dangerous chemicals. The directive can be viewed as inherently providing for three levels of proportionate controls in practice, where larger quantities mean more controls.

The directive contains general and specific obligations on both operators and the authorities of the Member States. The provisions broadly fall into two categories related to the twofold aim of the directive: control measures aimed at the prevention of major accidents and control measures aimed at the limitation of consequences of major accidents. Controls are required in the areas of safety management systems, emergency plans, land-use planning, information for and consulting with the public, accident reporting and inspections.

The Directive is addressed to the Member States. They should bring into force the laws, regulations and administrative provisions necessary to comply with the Directive.

North American Agreement on Environmental Cooperation

Canada, Mexico, and the United States entered into the North American Agreement on Environmental Cooperation (NAAEC), a complement to the environmental provisions of the North American Free Trade Agreement.[2] To implement the NAAEC, the participating countries established the Commission for Environmental Cooperation (CEC) to address regional environmental concerns, help prevent potential trade and environmental conflicts, and promote the effective enforcement of environmental law.

The CEC has a number of initiatives that are directly related to public health management of chemical incidents. As part of the North American Agenda for Chemicals Management, the member countries are working on areas that benefit from cooperation on a regional scale (including environmental monitoring and human health risks of sentinel chemicals) and strive to improve environmental performance of economic sectors in the region. Another CEC initiative is to compile and disseminate information on the amounts, sources, and management of toxic chemicals from industrial activities in North America. As a final example, the CEC

1 http://unece.org/env/teia/intro.htm

2 North American Agreement on Environmental Protection Between the Government of Canada, the Government of Mexican States, and the Government of the United States of America, 1993.

works to build capacity for prevention of pollution in Canada, Mexico, and the United States by undertaking case-studies to demonstrate the advantages of pollution prevention, aiding the distribution of relevant information to stakeholders, and creating sources of financing for pollution prevention projects.

2.4.3 National laws

International agreements and regulations need to be implemented into national laws to be fully effective. In addition, national laws in the field of health care, public health, emergency planning and response, national safety, environment, labour and many others may have relevance for the public health management of chemical incidents.

2.4.4 International tools

In addition to international agreements, international organizations provide guidance and tools to assist countries in meeting the obligations of the international regulations. One of these tools, provided by the UNEP [1], is for the Awareness and Preparedness for Emergencies at Local Level (APELL). This is a modular, flexible methodological international tool for preventing accidents and, failing this, it aims to minimize their impacts.[2] This is achieved by assisting decision-makers and technical personnel to increase community awareness and to prepare coordinated response plans involving industry, government, and the local community, in the event that unexpected events should endanger life, property or the environment.

For special applications such as port areas, mining and transport separate guidance was introduced (e.g. TransAPELL, Guidance for Dangerous Goods Transport Emergency Planning in a Local Community).

Another UNEP tool is the Framework for Chemical Accident Prevention. The Framework offers Guidance for governments[3] wanting to develop, improve or review their chemical accidents prevention programme.

[1] United Nations Environment Programme
[2] APELL.(http://www.unep.fr/scp/sp/) and TransAPELL (http://www.unep.fr/scp/sp/publications/)
[3] Guidance for Government (http://www.unep.fr/scp/sp/).

The Guidance brings together in one document both in-depth information on critical elements of a chemical accident prevention programme based on international references and practical information addressed to national governments on how to develop such a programme.

More specifically, the Guidance provides comprehensive information for establishing a chemical accident prevention programme by:

- describing the steps that are needed before developing and implementing laws, regulations, policies, guidance or other instruments which would make up an effective chemical accidents programme;
- setting out the possible elements of such instruments; and
- providing resource materials related to how these elements may be implemented, based on international initiatives and the experience of countries.

The Guidance focuses on prevention and preparedness for accidents at "hazardous installations" which include places where hazardous substances are produced, processed, used, handled or stored in such quantities and under such conditions that a chemical accident could occur. The types of accidents addressed by the Guidance would include any loss of containment, explosion, or fire involving chemicals which pose a hazard to human health or the environment.

In addition to the United Nations, the Organisation for Economic Co-operation and Development (OECD) has introduced Guiding Principles for Chemical Accident Prevention, Preparedness and Response[4] with sections on prevention, emergency preparedness/mitigation, emergency response, follow-up of incidents and some special issues. For each of the target groups, industry (including management and labour), public authorities, communities and other stakeholders, specific guidance is provided for each stage of the disaster cycle.

[4] OECD guiding principles (http://www2.oecd.org/guidingprinciples/index.asp).

CASE STUDY 5: EXPLOSION OF A FERTILIZER FACTORY – TOULOUSE, FRANCE

At 10:15 on 21 September 2001, a huge explosion ripped through AZF (Azote de France), a fertilizer factory located in the outskirts of the city of Toulouse, France. Thirty-one people died in the event and approximately 2500 were injured. More than 500 homes became uninhabitable.[a] The blast blew out the windows of houses located several kilometres away.

The explosion occurred in a warehouse in which 200–300 tonnes of granular ammonium nitrate were stored. The exact cause of the incident is still unknown. The plant also contained large amounts of chlorine and ammonia and was located very close to some facilities storing phosgene and gunpowder. Fortunately, none of these other chemicals were released by the incident, partly because of strict safety regulations regarding the storage of explosives.[b]

The emergency response to the incident was characterized by a lack of coordination and communication among the various stakeholders.[c] Telephone lines were cut off by the blast and the roads quickly became jammed with traffic, making any evacuation, in this case, extremely difficult. The health care services in particular complained about the lack of information, which limited their ability to follow a general emergency plan. Subjected to contradictory messages from the media, the public did not know how to behave, which fuelled a long-term distrust of the government.

The tragic outcomes of the incident were mostly a result of the inability to assess properly the risks linked with the storage of ammonium nitrate in the facility. Although AZF was classified as a high-risk factory, it seemed that no one had considered the possibility that an explosion of ammonium nitrate could be a likely incident scenario. As a result, the warehouses containing ammonium nitrate had not been inspected for some time. In addition, because the local authorities had focused their evaluation on the risks associated with chlorine, ammonia and phosgene, they had underestimated the magnitude of the safety zone required to protect individuals from an ammonium nitrate explosion. Therefore, residential areas were located too close to the plant.

KEY POINTS

- Prevention of chemical incidents necessitates a proper assessment of the health and environmental risks associated with the chemical(s) (synthesis, storage, transport and utilisation) of interest. Creation of a national database recording all chemical incidents or near incidents can facilitate better estimation of the risks to health and the environment. For example, the recurrence of small incidents linked to a particular chemical could serve as a warning flag for potential risks, which if properly addressed could help prevent a major incident. A better estimation of the risks to health and the environment linked to a chemical can also be obtained by reviewing chemical incidents worldwide. The experience gained by others during major incidents can then be used to improve the national or local prevention measures, as well as the preparedness plan.
- Consider all possible incident scenarios, even those that may not appear very likely.
- The preparedness plan should include public communication. A lack of information can lead to a population response that may interfere with the emergency response.
- The lack of coordination in Toulouse during the early hours of the incident response shows that the preparedness plan should require the presence of an emergency communication channel, should the telephone lines and electricity be cut off during a chemical emergency.

[a] UNEP. *Ammonium nitrate explosion in Toulouse, France.* United Nations Environment Programme (http://www.unep.fr/scp/sp/disaster/casestudies/france/).
[b] Barthelemy F. et al. *Rapport de l'Inspection Générale de l'Environnement.* Usine de la Société Grande Paroisse à Toulouse, accident du 21 septembre 2001.
[c] Ministère de la Santé. *Explosion de l'usine AZF de Toulouse le 21 septembre 2001 : enseignements et propositions sur l'organisation des soins* (http://www.sante.gouv.fr/htm/actu/azf/2azf.htm).

2.5 PREVENTION OF CHEMICAL HAZARDS FOR THE PUBLIC

2.5.1 Public education and awareness

Chemicals are everywhere and many are part of our daily life. Some chemicals can be highly hazardous to the public if they are mishandled. Inappropriate use of chemicals can lead to acute or chronic exposure and cause serious public health concerns. As was illustrated by the mass poisoning in India (section 4), page 51 the public can be tragically ill-informed of the risks that some chemicals pose to their health. In this case, people in a rural area were using containers that had formerly contained pesticides as cooking vessels. Such an incident could have been prevented by public education. Increasing the general public awareness of the dangers linked to the misuse of some common chemicals should therefore be a priority, especially in developing countries where awareness of chemical hazards may be limited.

The public (including workers) should be informed about the specific hazards in their residential and working areas, such as the presence of chemical installations and transportation routes or pipelines. Open communication and identification of hazards will build the trust between the public, (plant) operators and authorities which is also a prerequisite for meaningful and effective crisis communication in the event of a chemical incident.

The availability of infrastructure to support risk-avoiding behaviour is essential, in addition to provision of information on risk. The public should have access to shelter, to escape routes with sufficient capacity, and a crisis communication channel (e.g in the form of a dedicated radio station). These provisions help to reduce the population's vulnerability (strengthen resilience).

2.5.2 Identification and protection of vulnerable populations

Susceptible subpopulations exist in all groups of individuals. Such susceptible subpopulations may have a greater inherent risk of suffering adverse health effects from a chemical incident, for example, because:

- their exposure thresholds for health effects are lower;
- they receive a relatively high exposure;
- their mobility is reduced or their ability to protect themselves from exposure is reduced.

Some common examples of populations that must be considered when evaluating population susceptibility are children, pregnant women, elderly persons, hospital patients and people with low socioeconomic status. The actual list will vary by location and by toxic end-point to be considered. Once these groups of more vulnerable individuals have been identified, policy-makers should give special attention to their protection. This might include enforcing building or safety regulations on hospitals, schools or residential facilities for the elderly. This might also include more stringent controls on land-use-planning in areas close to a potentially vulnerable population as well as specific public education.

2.6 ROLE OF PUBLIC AND ENVIRONMENTAL HEALTH AND OTHER AGENCIES IN INFLUENCING POLICIES AND LEGISLATION

Although the legislation and regulatory measures designed to prevent the occurrence of a chemical incident are written by policy- and law-makers, all agencies and organizations involved in responding to a chemical incident emergency including public health should be responsible for identifying long-term strategies to reduce the probability of a chemical incident and limit its adverse consequences in case it does occur. All policy and legislation pertaining to prevention and mitigation of chemical incidents should be regularly reviewed and updated, if required, by the relevant agencies dealing with the various aspects of chemical incidents. Updates from each agency should then be provided for the attention of the responsible or coordinating organization, which should in turn provide guidance and oversight to the policy-makers. Preventive measures require coordination of agencies and information from a variety of sources. It is therefore important to coordinate the activities of the various agencies to avoid competing or duplicate regulations.

National legislation that requires locations containing hazardous chemicals to be registered in a National Hazardous Site Database would also enhance prevention and management of chemical incidents. It might also contribute to the establishment of mechanisms for the regulatory oversight of these locations, which will help to ensure proper usage of the chemicals, proper maintenance of the facilities and proper work training and protection.

The agencies involved in the response to a chemical incident may use the knowledge that they have gained after the incident, through health risk assessments or other studies, to inform policy-makers of important modifications of the legislation or the regulations that are necessary to prevent the recurrence of the incident. These long-term studies are described in section 6.2.

The role of local or national agencies in influencing policies and legislation is illustrated by the aftermath of the explosion of a fireworks factory in Enschede, The Netherlands (section 6.5, page 86).

Finally, public health has a role of its own to play by providing expertise and experience in the fields of health risk assessment (for land-use planning, siting and licensing), and contributing to an assessment of health care needs and capacity for incident scenarios. In addition, the public health community's expertise and experience in risk communication might prove invaluable for the prevention of chemical incidents.

CASE STUDY 6: TRAIN EXPLOSION DUE TO MIXING OF INCOMPATIBLE CHEMICALS – NEYSHABUR, ISLAMIC REPUBLIC OF IRAN

Early on the morning of 18 February 2004, 51 train cars containing various chemicals became separated from a train, rolled backwards down the tracks and derailed at the next station, causing a number of chemical leaks and a chemical fire. Local emergency services responded, and within hours were close to having the fire under control.

As response teams attempted to extinguish the fires and contain the incident, a large explosion occurred that caused widespread damage and casualties. The explosion, which was felt up to 70 km away, destroyed most of the buildings and homes along the track and caused significant damage to five nearby villages. The explosion claimed hundreds of lives as well as causing injuries among the local fire crews and relief workers who responded to the incident, and among the onlookers.

The derailed cars contained a variety of chemicals including 17 cars of sulfur (flammable solid), six tank cars of gasoline (highly flammable liquid), seven cars of fertilizers (explosive when mixed with flammable liquids), and 10 cars of cotton wool. The explosion was caused by the pooling and mixing of incompatible chemicals that had leaked following the derailment and were exposed to heat from the subsequent fire.

The casualties that resulted from this explosion might have been avoided if the emergency responders had had knowledge of the chemical content of the rail cars.

KEY POINTS

- Information on the content of rail cars and other modes of transportation is regulated by adoption of the UN Recommendations for the Transport of Hazardous Goods into national law.
- These recommendations require that labelling follows the Globally Harmonized Classification and Labelling System (GHS).
- To help minimize accidental exposures, international agreements need to find their way quickly into national legislation.
- Decision-makers need to understand the risks of a given situation as quickly as possible to avoid unforeseen outcomes such as explosions.

3 EMERGENCY PLANNING AND PREPAREDNESS

A chemical emergency can have severe impacts on both public health and the environment. The likelihood that a chemical incident will occur can be greatly reduced through implementation of the various preventive measures, described in section 2. But even with a good prevention system, not all incidents can be avoided and there is always a residual risk that an incident may occur. An essential role of the agencies involved in response to a chemical emergency is therefore to minimize the impacts resulting from these potential incidents.

The most effective method for minimizing the negative outcomes of an incident is to respond to the emergency in a timely and appropriate way. Because chemical incidents are by nature complex and often acute, such a response can only be achieved through the coordination and proper preparation of the various agencies that may be involved in responding to an emergency. Any time taken during an incident to identify vulnerable infrastructures, locate materials and personnel and establish communication with other agencies will be time lost in addressing acute concerns. This requires both emergency planning and preparedness activities. Emergency planning is concerned with the design, set-up and maintenance of an effective emergency response infrastructure. Emergency preparedness is the result of the execution of the emergency plans, tailored to each individual foreseeable hazard.

This section will describe the steps that should be taken to ensure that the response to an incident is really focused on the acute concerns. The text will focus on the (public) health planning and preparedness. The public health sector can only function well if all the other sectors involved plan and prepare equally well and preferably in a coordinated manner.

Emergency planning will result in plans, procedures, guidelines, and relevant information on incident management. While these are crucial for the response to the incident, the multidisciplinary process of drafting those plans itself is probably at least equally important. It offers an opportunity to build trust and understanding among those agencies and individuals who will be charged with the response if and when an incident occurs.

3.1 GATHERING USEFUL INFORMATION

At the time of an incident, it is crucial for responders to have access to information that can help guide the appropriate response. Databases should be established for **hazardous sites**, **contents of transportation** (e.g. containers or ships), **chemical information**, **health care resources**, and **emergency contact information**. All databases should be integrated and updated regularly (requiring an update protocol), to ensure that the information necessary in a given situation is readily available and accurate. During an emergency, the time required to access key information could prove critical to first responders. Ideally, these databases should be computerized and available to key personnel. Additional features, such as ability to sort by location, chemical hazard, or other criteria would be useful. It is very important to recognize that all of the databases discussed below are "living documents" which will need to be continually updated as new sites are identified or as sites change. For example, local public health agencies should continuously provide up-to-date information regarding health care sector capabilities to the national agency in charge of the management and integration of the databases.

3.1.1 National hazardous sites database

A database or inventory of hazardous sites is an important means of identifying the location and magnitude of potential chemical releases. To be useful for an actual response, the information on the chemicals should be very up to date (less than a day old). Access to information on specific chemicals and sites will provide first responders with crucial information during the initial stages of a chemical incident. Important information that should be included in a database is listed Box 2.

The most effective means of acquiring the information needed to develop a national hazardous sites database is to enact legislation requiring facilities to register with a governmental agency. As was previously discussed in section 2.3, this legislation should include criteria for identifying hazardous sites. These criteria may be based on, but are not limited to, specific chemicals, chemical mixtures and/or categories of chemicals, and their potential to cause harm to health and the environment. If a national inventory does not exist and legislation is lacking, a national database will need to be developed. One method of collecting the information needed for the development of the database is to provide incentives to operators that choose to register voluntarily. Another efficient method to create and maintain a national database is to acquire local inventories and assemble them into a larger, national database. A local multidisciplinary emergency planning team (including public health) or coordinating centre is likely to be the most qualified to compile a local inventory of hazardous sites, although other groups such as universities or other local agencies may be required to provide services for its completion. Thus, information regarding specific sites in communities can be gathered from a variety of sources.

BOX 2: INFORMATION THAT SHOULD BE FOUND IN THE NATIONAL HAZARDOUS SITES DATABASE

As a minimum, the database should include:

- location of the hazardous site
- chemical(s) found on the site
- actual quantity/quantities of chemical(s) found on the site, including intermediates and waste products
- contact information for the management of the site.

In addition to this primary information, the database might include:

- existence of an emergency and evacuation plan for the site
- materials and first aid available on-site
- presence of decontamination equipment, for personnel on-site, patients, first responders and equipment
- presence of therapeutic measures including antidotes
- availability of relevant expertise among on-site personnel
- modelling of potential chemical release scenarios
- estimated size and location of vulnerable areas
- major transportation routes of a chemical.

Because the site operators have the greatest knowledge of a site, they should be required to provide information about their site, either through legislation or as a precondition to licensing the facility. An alternative source of information could be local planning officials. These individuals may have access to information through local planning regulations that may require companies to prepare plans for their sites and describe their use. In the case of non-official and non-regulated sites, a valuable source of information can sometimes be found in the local communities, especially if the site is perceived as a threat to public health.

After a national database has been compiled, it may be useful for national officials, with input from local officials, to prepare a ranking of the most hazardous sites. The ranking can be based on many attributes of the site including:

- the chemical characteristics (reactivity, volatility and persistence), including how they may react in a manner that causes an incident;
- volume of chemicals or of by-products produced and stored at the facility;
- types of chemical processes conducted at the site and any risks associated with these processes;
- variability of the inventory, type and amount of chemicals in the process as intermediates, and waste products; and
- site characteristics such as age of the facility, safety of the storage conditions, existing safety measures, and proximity to population centres or essential natural resources, such as drinking-water supplies.

3.1.2 Chemical information databases

The national government should arrange for chemical databases to be purchased and installed, and/or establish 24-hour electronic access to the chemical databases as an integral component of preparedness plans. Information in the chemical database should include:

- **Physicochemical characteristics:** Information about physicochemical properties is crucial since this information will influence a chemical's fate and transport, potential interactions with other chemicals, and how it may affect potentially exposed populations. Information regarding chemical properties, such as, reactivity and potential hazardous reactions with water or fire extinguishing agents might be crucial during an emergency. Such information can be found online in the database developed by the Canadian Transport Emergency Centre of the Department of Transport (CANUTEC).[1]
- **Health and environmental effects:** The database should include information regarding potential effects of chemicals on human health and the environment. Information should also cover both acute and chronic health effects, for exposures occurring via ingestion, dermal contact, or inhalation. Information should also be included regarding potentially susceptible subgroups. With respect to environmental effects, information should be included regarding target species and effect levels.
- **Testing protocols:** The database should include information regarding testing protocols and equipment for determining chemical exposures both in the immediate aftermath of a chemical incident and during subsequent remediation efforts. Information on testing should include appropriate biological and environmental testing protocols.
- **Decontamination procedures:** Information about the appropriate chemical-specific decontamination procedures for response personnel (wearing chemical protective clothing), victims and equipment should be included in the database. This information should also be specific to the type of chemical incident, for example a spill or a fire.
- **Medical information:** Information about the medical signs and symptoms of exposure and methods for the treatment of people exposed to chemicals should be included in the database. In addition, any information about therapeutic measures including information on antidotes to chemicals should be

WEB LINKS 1: CHEMICAL INFORMATION DATABASES

- INCHEM: http://www.inchem.org
- CAMEO, the US National Oceanic and Atmospheric Administration and the US EPA's electronic information management system: http://www.epa.gov/emergencies/content/cameo
- UK HPA: http://www.hpa.org.uk/webw/HPAweb&Page&HPAwebAutoListDate/Page/1153846673455?p=1153846673455
- WISER: http://wiser.nlm.nih.gov/
- HSDB, TOXLINE and IRIS can be accessed via TOXNET: http://toxnet.nlm.nih.gov/
- IUCLID, the EU database on toxicity of chemicals: http://ecbwbiu5.jrc.it/
- ESIS, the European Union Chemical Information System: http://ecb.jrc.it/esis/
- OECD Integrated HPV database: http://cs3-hq.oecd.org/scripts/hpv/
- http://www.who.int/environmental_health_emergencies This WHO site presents relevant information regarding chemical risks to health during incidents and emergencies

[1] http://www.tc.gc.ca/CANUTEC/en/menu.htm

included. The chemical information database might also include information about medical treatments that can be used as a follow-up to exposure to a specific chemical.

3.1.3 Health sector capabilities databases

With the assistance of local public health teams and coordinating centres, a national database of health sector facilities should be developed. The availability of adequate health care facilities and adequately trained health care staff is crucial to the successful management of any chemical incident. In addition to information regarding the number of facilities in a given area, facilities should be assessed regarding their medical equipment, decontamination equipment, medicines, antidotes and toxicology laboratories. Decision-makers will need access to this health care information to plan their response and to provide guidance to health care professionals on how to respond to a chemical incident. This information will also be useful to identify areas where improvements in the health care system are required to enable an adequate response to a chemical incident.

As shown by the toxic wastes crisis in Côte d'Ivoire (section 3), page 42, local health care facilities can be rapidly overwhelmed during a chemical emergency, especially if the injuries involve burns or severe toxic symptoms. This can happen even with a small number of casualties. A casualty distribution plan, if necessary for specific health conditions (burns or chemical injury) is an essential tool for mass casualty management. Access to facilities in neighbouring districts that are further afield may therefore be necessary. Identifying where these facilities are is an important step in the planning and preparedness phase in order to regulate the flow of patients.

Access to emergency medical and public health personnel might also be critical. Information from the health sector database would enable decision-makers to develop contingency plans to manage a major chemical incident.

3.2 PREPARATION OF A CHEMICAL INCIDENT RESPONSE PLAN

Planning for major incidents and disasters has been comprehensively developed throughout the world. Depending on the level of development and awareness of a society, there will often be a general plan covering emergencies. This plan is often derived from existing plans covering the roles of emergency and health care services in most types of incidents likely to involve an emergency response (including fires and disease outbreaks). Because the existence of a chemical incident response plan is a key factor in the timely response to a chemical emergency, it is very important to have a well-developed plan in place. Even more importantly, the process of putting such a plan together creates an opportunity to liaise, network and gain an understanding of future partners in emergency response and build mutual trust. However, because the issue is very complex and typically requires input from a wide variety of agencies and organizations, plans designed to deal specifically with the dangers linked with a chemical release are often absent or poorly developed. As such, creating and updating a national chemical emergency response plan is one of the major components of public health management of chemical incidents.

3.2.1 Framework for planning of the chemical emergency response

Before starting the process of producing a national public health chemical incident response plan, a decision should be made as to where the plan will "reside". The plan could then be any one or a combination of the following:

- a stand-alone plan that will need to be adopted by several organizations or agencies;
- a plan integrated into a public health plan (e.g. for an outbreak of food poisoning or an infectious disease);
- a plan integrated into the emergency services chemical incident plan;
- a chemical incident plan integrated into the broader emergency services major incident plan. This specific plan would take into account the potential impacts

of a chemical release on public health and the environment;
- a plan would need to cover detection, alert and scaling up, command and control, training and exercise, public crisis communication and health sector communication.

Whichever framework is chosen, considerable thought must given to ensuring that the plan is coordinated with the other relevant but nonintegrated plans. Plans should be developed in close cooperation among, and with input from, all the stakeholders that will need to interact during a chemical incident. The plan will also be significantly improved if key members of the local community are involved throughout the development process.

The seven major chemical release scenario types that the public health response plan for chemical incidents will need to address are listed below (for a detailed description see section 1.2.2):
- sudden evident release of a gas or vapour outdoors;
- sudden evident release of mist or dust clouds;
- sudden evident release to contact media other than air;
- fire in a large building;
- explosion;
- disease outbreak;
- silent release.

The seven types of incident scenario each have four components: the type of release (detected or undetected), the type of chemical (known or unknown), injury mechanism (toxicity, blast or heat) and the type of source (fixed or moving). A fifth component, whether the source is regulated or unregulated, can be added to the matrix. Both detected and undetected releases most often occur from a non-registered or unregulated site. Although sites registered with the hazardous site inventory described in section 3.1.1 can still generate releases, typically these releases are readily detected and the identity of the chemical is known. A detected release of an unknown chemical may occur from a source not listed in the hazardous site inventory, illegal or uncontrolled dumping of chemicals, or as the combustion products of a chemical fire. An example of a detected release of a known chemical from a non-fixed source is a release from a well-labelled tanker truck. A silent release, where the release is unknown or was thought to be harmless, may be a slow release of a chemical into waterways or into the air. As exemplified by the case-studies throughout this document, each of these release scenarios can be caused by a variety of events, including but not limited to human error, equipment failure, weather events and other naturally occurring events such as earthquakes and volcanic eruptions, criminal acts or neglect of and inattention to the dangers associated with a chemical.

The chemical emergency response plan should establish a clear and coherent framework of actions to be taken in case of a chemical emergency. The chemical emergency response plan should also specify general binding requirements, such as international agreements or legislation as discussed in section 2.3. In addition to implementing international conventions and national legislation, the national plan should include procedures to:
- Ensure that resources (finances, staff, equipment, infrastructure and training) are available for local networks involved in management of chemical incidents.
- Establish a national database of hazardous sites (section 3.1.1).
- Coordinate inter-agency relationships and collaborations (section 3.5.1), e.g. on contributing to health and exposure investigations during the incident.
- Develop and implement a national model of command and control (e.g. based on ICS, see section 3.4) including procedures for scaling up the incident response from the local up to the (inter) national level.
- Develop procedures to inform the public concerning hazardous installations and to help to ensure that the public understands this information.
- Coordinate relationships and collaborations

with neighbouring countries and international organizations such as WHO.
- Conduct or sponsor routine activities such as national-level exercises (section 3.6).
- Develop a quality assurance control procedure to identify gaps in services and to monitor the effectiveness and efficiency of local multi-disciplinary chemical emergency response groups (section 3.6).
- Ensure that national assistance such as laboratories, antidotes, decontamination equipment and experts will be provided to local responders.
- Ensure that national public health information is acquired on a regular basis.
- Identify and correct internal weaknesses at both the national and local levels.

3.2.2 Local emergency planning guidelines

Uniform guidelines and standards for developing local emergency plans for chemical incidents on-site and off-site should be established. National guidelines prescribing minimum requirements for local plans can help to ensure their quality, consistency and interchangeability. These guidelines can be used by local teams that will be responding to incidents and for their training and exercise. Development of a set of credible incident scenarios is the starting point for this activity. All parties, including operators of hazardous installations and possible sources of incidents, should be included in this process.

Local plans should take into account the range of possible health effects (i.e. acute, delayed and chronic) that result from chemical incidents. In particular, the local plans should emphasize the need to protect susceptible populations as well as health care workers and other emergency responders from exposures to hazardous chemicals. The guidelines should also include instructions on how to handle chemicals in case of an emergency. For example, they might recommend specific chemicals or activities to use or to avoid when responding to the hazardous substance that has been released, whenever possible; this often involves input from fire service hazardous material specialists in the planning. Plans should also include operational information such as where to set up an emergency coordination unit, access to electricity, water and other facilities. In addition, local plans should make reference to more detailed plans by both local public health chemical incident response teams and entities such as hospitals, as well as chemical incident response plans for specific hazardous sites.

Local plans should be integrated into the broader emergency plans that deal with natural disasters and acts of terrorism. This integration should result in coordinated and consistent emergency plans.

Finally, the local chemical emergency plans should be used by the responsible agencies to familiarize themselves with the specific information on the sites in their jurisdiction, including information regarding the chemical and physical properties and locations of the hazardous chemicals. Having this information in advance will result in a more focused and timely response.

BOX 3: INFORMATION THAT SHOULD BE PROVIDED IN A LOCAL CHEMICAL EMERGENCY RESPONSE PLAN

- Roles, competencies and responsibilities of all the local agencies and organizations that might be involved in the response to a chemical incident. The chain of command and coordination between agencies and other organizations should be clearly outlined.
- Relationships between the various local agencies.
- Agreement regarding who will pay for the analyses of samples taken in connection with an emergency.
- Definition of the conditions needed to request national assets.
- Establishment of procedures and means by which the public will be notified about the incident.
- Identification of a mechanism for annual review and assessment of the chemical emergency management plan.

CASE STUDY 7: DELIBERATE RELEASE OF CHEMICAL WARFARE AGENT – TOKYO, JAPAN 1995

On 20 March 1995, members of the *Aum Shinrikyo* cult released the nerve agent sarin into the Tokyo subway system, hoping to sow public fear and inflict mass casualties on commuters. The attackers filled plastic bags with sarin and then punctured the bags in five trains entering an underground station. The attack left 12 dead, 54 critically injured and affected thousands.

The effectiveness of the emergency response to this intentional release of a hazardous substance was hindered by a lack of information about the nature of the threat. Although the intelligence and security services were warned of the possibility of a terrorist attack with toxic chemicals, they failed to alert emergency services. Therefore, first responders and hospital officials did not know the cause of the injuries or the size of the population at risk. As a result, only limited efforts were made initially to contain and decontaminate the areas known to be affected. Although authorities were able to identify the agent three hours after the initial attack, they were not able to share the information rapidly with local hospitals because a network for communicating emergency information had not yet been established. Fortunately, response to the release was facilitated by knowledge that the group had made a similar attempt a few months previously. As a result, health care providers and security agencies were aware of symptoms associated with sarin and able to respond appropriately within a relatively short time.

KEY POINTS

- Good communication between the security and the health care sectors is essential when dealing with the threat from the deliberate release of chemicals.
- Chemical incident response plans should incorporate communication channels between public health authorities and other entities such as hospitals and first responders. More non-traditional communication channels with security/intelligence services should also be opened.
- Frequent and regular training of authorities and responders to deal with various scenarios and symptoms associated with chemical agents is a critical element of the chemical incident response plan.

BOX 4: THE SPECIAL CASE OF THE DELIBERATE RELEASE OF A CHEMICAL

The deliberate release of a chemical to harm a population is a special challenge to responders. In the case of a threatened release, the alert will generally come from the nation's security or defence sectors or from the media. In other cases the incident will present as a disease outbreak or a silent release. In both cases the response to the emergency is provided by the emergency and public health sectors. The first challenge posed by this type of emergency is the necessity for effective communication between non-traditional stakeholders, such as security and public health sectors. In addition to this specific challenge, the forensic and security concerns triggered by the deliberate release of a chemical might also mean that the amount of information available to the chemical emergency responders, as well as access to this information, may differ from that for other types of incidents and emergencies.

As a general rule, preparation for the deliberate release of a chemical might include:

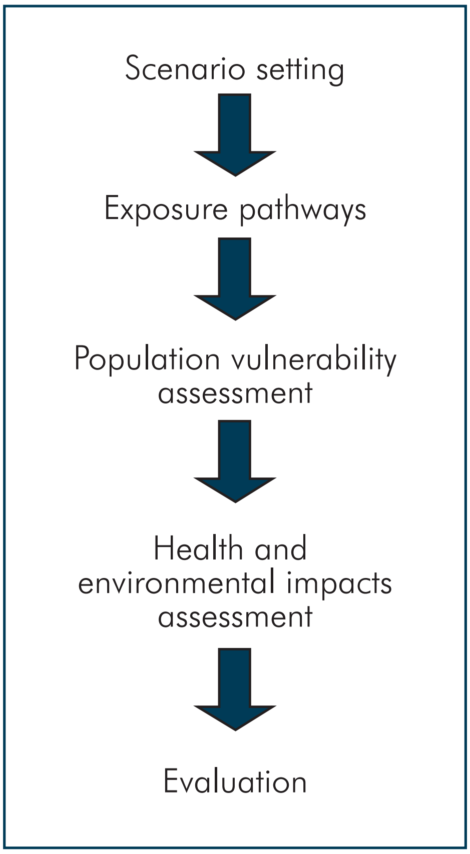
- restriction of access to hazardous chemicals;
- identification of the location of critical medicines and other essential commodities;
- improved assessments of vulnerable populations;
- dissemination of information to professionals and members of the public, particularly those thought to be at greatest risk;
- improved surveillance of disease outbreaks, especially clusters of cases with unusual symptoms;
- strengthening of existing food-safety structure;
- better communication between public health agencies, water supply, food safety, poison centres and other services and better coordination of their responses in case of an emergency;
- creation of contingency plans with the ability to enlist resources such as civil defence and security services.

WEB LINKS 2: EMERGENCY PLANS

For some examples of templates (not necessarily endorsed by WHO) and further information on developing local emergency response plans, visit:

- Health sector: http://www.bt.cdc.gov/planning/
- Municipal and corporate level: http://www.ccep.ca/ccepbcp5.html
- Water sector: http://www.nj.gov/dep/watersupply/erp_template_10_04.doc, and: http://www.doh.wa.gov/ehp/dw/security/331-211_5-13-03_Emergency_Response_Planning_Guide.pdf
- Environmental incidents: http://www.dem.ri.gov/topics/erp.htm
- Food incidents: www.nasda.org/File.aspx?id=11167

FIGURE 6: STEPS IN A COMMUNITY IMPACT ASSESSMENT



3.3 COMMUNITY IMPACT ASSESSMENT

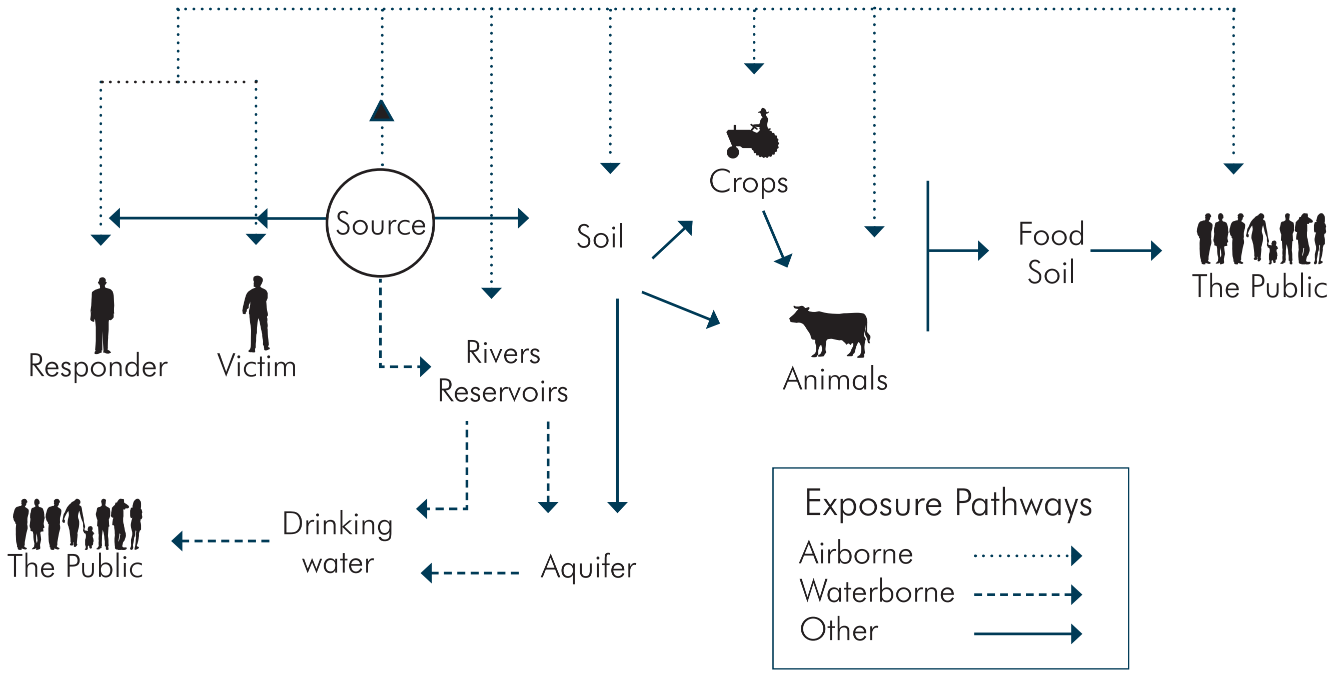
One of the primary responsibilities of local public health teams is to conduct community impact assessments for the hazardous sites located in the community or region, based on scenario studies of possible releases, as identified in the national hazardous sites database described in section 3.1.1. This is essentially the same activity as risk assessment *during* an emergency; however impact assessment in the preparedness phase will have to rely on model projections of possible exposure, whereas during an incident the risk assessment will be (partly and ultimately) based on actual exposure data.

A community impact assessment is a qualitative or quantitative assessment of the likelihood of adverse effects resulting from a possible future chemical incident. Hazard, on the other hand, is a term used to describe the inherent properties of a compound which may cause harm. A community impact assessment comprises five steps.

1. **Scenario setting:** For each site or transport route, the local public health team should develop potential incident scenarios, including the likelihood of release of each of the chemicals on-site currently or in the future or in transportation. These scenarios should be credible, and the selection of scenarios for further review should focus on those with major consequences. Review of circumstances associated with previous incidents or near-incidents at the site or at another comparable site can help identify credible scenarios.

2. **Exposure pathways:** Chemicals can migrate from the incident site to surrounding communities in air or water. This can result in contamination of soil, water and air, with a potential for exposure through ingestion of and dermal contact with soil and water, and inhalation of airborne contaminants. For each site and chemical, the zone surrounding the facility that is vulnerable to exposure should be determined based on the likely transport media, as well as other site-specific information such as topography, water bodies, and meteorology. This information can be used to generate computer models to map the vulnerable zone. Once the vulnerable zone has

FIGURE 7: EXPOSURE PATHWAYS[a]



[a] Reproduced from CrisisTox Consult with permission.

been mapped, it may be necessary to study land uses within the zone. If there is agricultural land within the zone, food contamination may also be a concern. Figure 7 provides insight into possible exposure pathways. Further details regarding computer models are given in section 5.3.

3. **Population vulnerability assessment:** Once vulnerable zones have been identified, populations within these zones should be identified. Population data, if available, should be used to estimate the number of residents in the vulnerable zones. However, at any given time, areas may have many more people in them, for example, working populations, tourists, and visitors. Special attention should be given to susceptible subpopulations, such as, but not limited to, children in schools, elderly people in residential facilities, hospital patients, and people in lower socioeconomic classes. Susceptible populations may be more at risk due to lower thresholds for health effects following exposures, reduced mobility hindering their ability to vacate an exposed area quickly or to lack of access to shelter. In addition to these susceptible subgroups, the population vulnerability assessment should include on-site individuals including subcontractors and emergency responders, who are likely to be exposed to higher concentrations of the chemical(s) than the general population. More information on identification of vulnerable populations is provided in section 2.5.2.

Facilities and structures in and around the vulnerable zones, which provide essential services, such as hospitals, or those that could be used as shelters, such as stadiums, schools and community halls, should also be identified. Additionally, areas where contamination would have significant effects such as farmland, water bodies, recreational areas and areas that support wildlife should also be considered. Finally, the possible consequences of an incident for nearby chemical or industrial facilities should be assessed, including the possibility of domino scenarios.

Assessing the vulnerable area around chemical transportation routes may present more difficulties; however toxic chemicals are often transported by roads and railways, which are likely to pass through densely populated areas. Therefore, people living in the vicinity of major transportation routes should be considered vulnerable.

4. **Health impact assessment:** The health impact assessment brings together the chemical characteristics, the pathway of exposure, and the population vulnerability assessment. This information is used to estimate the likely number and type of casualties, any delayed effects from acute exposures, and effects of secondary contamination (i.e. of soil and water) for the previously defined chemical incident scenarios. The health impact assessment should also include an estimate of the sheltering and evacuation requirements and the capacity of the emergency services to support them. Various computer models, discussed in section 5.3 are available to assist in this type of assessment. The assessment should include an evaluation of the likelihood that environmental and health impacts may cross administrative boundaries of any kind (e.g. via gas clouds or rivers) since this would complicate the response.

   Once the number and types of casualties are estimated, it will be necessary to translate these into resources required to respond adequately (in time, with the right number and quality of personnel and resources), such as for health care, evacuation and access to shelter (both in-place and in organized shelters). By comparing the incident requirements with the available resources, an assessment can be made of whether the local health care resources have adequate capacity to handle the aftermath of a chemical incident. This estimation should take into account the possibility that health care services may be overwhelmed not only by people affected by the chemical release, but also by people seeking free health care services, as happened in Côte d'Ivoire during the toxic wastes crisis section 3, page 42. If the health care services are overwhelmed, additional resources from other areas will be required ("mutual aid").

   The impact assessment should consider the environmental consequences of the chemical release, as these impacts can have long-term effects on public health. The potential for contamination of the vulnerable areas should be determined and potential strategies to manage the affected areas should be evaluated. The availability of the financial, technical or human resources required to minimize the environmental impacts should also be assessed.

5. **Evaluation:** The community impact assessment is concluded with each scenario being evaluated based on the probability of occurrence and the level of preparedness. Probability of occurrence may be difficult to ascertain. However, information such as historical incidents and current land use and operations may be helpful. In addition to information regarding the health effects of the specific chemical(s), the number of affected citizens and potential environmental impacts, the risk assessment should also evaluate any disruption of services and financial impacts. Community preparedness includes quantifying the health care resources available such as healthcare professionals and inpatient capacity at hospitals, the status of emergency response plans, the numbers of health care workers trained in responding to chemical incidents, and availability and proximity of backup resources. These factors may require only a qualitative estimate (e.g. "high", "medium" or "low"), whereas other factors (i.e. population at risk) may require quantitative assessments.

3.4 INCIDENT COMMAND

Responding to a major chemical incident is a relatively rare and complex undertaking, even for designated emergency managers. A clearly defined incident response system will facilitate this task. The Incident Command System (ICS)[1,2], is broadly accepted, recommended by the United Nations and is widely used in the United States and the United Kingdom. Other countries have implemented similar systems, such as New Zealand's Coordinated Incident Management System and Australia's Australasian Inter-Service Incident Management System (AIIMS).[3] The Major Incident Management and Support System (MIMMS) is an alternative specifically aimed at medical management.[4]

In addition, the ICS utilizes a standardized chain of command for every incident, regardless of size. This feature allows responders who may be from multiple disciplines and agencies to be consistently trained prior to responding to a chemical release. Therefore, public health officials will be familiar with the roles and responsibilities of the ICS when first arriving at the scene of an emergency. Thereby, the ICS enables all responsible agencies to manage an incident together by establishing a common set of incident objectives and strategies.

The ICS provides a standardized, on-scene and off-scene, all-hazard incident management concept. It allows management teams to adopt an integrated organizational structure to match the complexities and demands of single or multiple incidents involving multiple agencies; and includes all the personnel at the scene of an incident, such as first responders, public health personnel, emergency planners, personnel from environmental agencies, and toxicologists.

[1] United States Federal Emergency Management Association's Incident Command Review Materials (http://www.training.fema.gov/EMIWeb/IS/ICSResource/assets/reviewMaterials.pdf).
[2] United States Federal Emergency Management Association's Independent Study Course (http://training.fema.gov/EMIWeb/IS/).
[3] New Zealand Fire Service Commission. *The New Zealand Coordinated Incident Management System: Teamwork in emergency management.* Wellington, New Zealand, New Zealand Fire Service Commission, 1998.
[4] Burkle FM. Disaster management, disaster medicine, and emergency medicine. *Emergency Medicine*, 2001,13:143–144.

WEB LINKS 3: COMMAND SYSTEM

The US Federal Emergency Management Institute provides a training course in the Incident Command System at: http://training.fema.gov/emiweb/IS/crslist.asp

The ICS is organized in modules, which function within a top-down, command system and can be adapted for both large and small incidents. The principles of chain of command and unity of command help to clarify reporting relationships and eliminate the confusion caused by multiple, conflicting directives. Depending on the scale and impact of the incident, the following layers of command can become operational:

- Operational command (also referred to as "bronze" command): On-scene Incident Command Post (ICP) as described below.
- Tactical command (also referred to as "silver"): Usually off-scene command to control multiple ICPs, complex incidents with a large affected area, overall logistics, and so on.
- Strategic command (also referred to as "gold"): Off-scene command post with public and/or government officials in charge of strategic decisions.

Incident managers at all levels must be able to control the actions of all personnel under their supervision. A fundamental feature of the ICS during any response is the development of an Incident Action Plan, that:

- clearly specifies the incident response objectives;
- states the activities to be completed and by whom; and
- covers a specified timeframe, called an operational period.

When responding to an emergency situation, the ICS sets objectives based on the following priorities:

1. life saving
2. incident stabilization
3. property preservation.

Various types of operational locations and support facilities are established in the vicinity of an incident to accomplish a variety of purposes, such as mass casualty management, processing of supplies donated, and decontamination. ICS uses pre-designated incident facilities that may include:

- **Incident command post (ICP):** The field location at which the primary operational-level, on-scene incident command functions are performed. The ICP may be co-located with the incident base or other incident facilities and is normally identified by a green rotating or flashing light.
- **Base:** The location at which primary logistics functions for an incident are coordinated and administered. There is only one Base per incident. The Incident Command Post may be co-located with the Base.
- **Staging area:** Location established where resources can be placed while awaiting a tactical assignment.
- **Camp:** A geographical site, within the general incident area, separate from the Incident Base, equipped and staffed to provide sleeping accommodation, food, water, and sanitary services to incident personnel.

Another key concept of the ICS during responses is the use of integrated communications facilitated through:

- the development and use of a common communications plan; and
- the interoperability of communication equipment, procedures, and systems.

A clear chain of command is a fundamental part of effective ICS management. The chain of command is an orderly line of authority within the ranks of the incident management organization. This establishes a unity of command and allows responders to be organized during a chemical incident, which can often be an inherently unorganized event. Under unity of command and unless otherwise instructed by the lead agency staff, all personnel:

- report to only one supervisor;
- maintain formal communication relationships only with that supervisor.

3.5 COMMUNICATION

3.5.1 Inter-agency communication

In the event of any chemical incident, a timely and robust mechanism is needed to notify and mobilize appropriate national and local governmental agencies, nongovernmental agencies, and responders to coordinate the response with the organization where the incident took place. The alerting mechanism needs to be regularly tested and upgraded. The contact information obtained for the alerting mechanisms can also be used to facilitate education and coordination among local, regional and national agencies to help ensure effective prevention of and responses to chemical incidents. Depending on the situation, organizations that need to be notified of an incident include local agencies that may be involved in responding to a chemical incident, other governmental and nongovernmental institutions, neighbouring or other countries and international organizations.

Inter-agency communication protocols and technical resources should also facilitate secure sharing of incident-related information, such as identity and amount of the released chemicals, number of casualties and their location, resources deployed, expected evolution of the incident.

3.5.2 Risk and crisis communication – information and public warnings

Public communication may be one of the most challenging aspects of a chemical emergency. A lack of communication or poor explanations can lead to undesirable and even risk-enhancing behaviour among the population and contribute to negative health consequences. For example, the consequences of a lack of communication were observed during the Bhopal gas incident: not knowing what to do, many people chose to flee and thus were exposed to the methyl isocyanate gas. If these people had been informed in a timely manner, they may have known that the best emergency protection against the chemical was to lie on the floor in an enclosed space with wet cloths on one's face. Many lives would probably have been saved if people had been aware of such a simple safety measure. It is important to acknowledge that risk and crisis communication are a process in themselves, requiring input from specialists.

Risk communication to the population includes all communication before an incident has actually taken place. This may include information on hazards in the vicinity, possible incident scenarios, preparedness by the authorities, protective actions that the public can take if an incident occurs and establishment of a communication channel. Risk communication builds trust between the potentially affected population, emergency responders and public professionals. As such, it lays the foundation for effective crisis communication.

Communication during an incident is usually referred to as crisis communication, and is an extremely important tool in enabling the response agencies and public officials to mitigate the consequences of the incident.

The public communication process during an emergency should respect several rules that are described in section 5.6. Throughout the incident, a

CASE STUDY 8: CONTAMINATION OF DRINKING-WATER FOLLOWING EXPLOSION AT CHEMICAL PLANT – SONGHUA RIVER, CHINA

On 13 November 2005, an explosion occurred at the Jilin Chemical Industrial Company plant in Jilin, China, killing five people and releasing 100 tonnes of pollutants, including benzene, into the Songhua River. The river is the main source of water for Harbin, China, a city with a population of over 3 million, located 380 km downstream from Jilin. The Songhua River is also a tributary to the Amur River in Russia, which flows to the Sea of Okhotsk.

The pollutants formed a chemical slick that reached Harbin on 24 November. By that time, the slick was 80 km long. The city government shut off water for four days, during which time the concentration of benzene in the river increased to 33 times the national safety level before decreasing to acceptable levels. To provide clean drinking-water, more than 50 wells were drilled and government agencies supplied bottled water. Residents of Harbin were also advised to stay away from the river to avoid possible airborne contamination. In addition, China's State Environmental Protection Administration (SEPA) increased the flow of the hydro-power stations to dilute the pollutant and set up water quality monitoring stations along the Songhua River.

By the time the chemical slick reached Khabarovsk on the Amur River in Russia, several weeks after the explosion, it was 150 km long. Although details of the explosion were slow to become available, the Russian authorities had enough time to increase production of bottled water from 75 to 1525 tonnes per day, and to establish 165 points where water could be distributed to the public.

Due to the international nature of the Songhua River incident, coordination and cooperation between Chinese and Russian officials reached the highest levels of government. A joint Chinese–Russian water monitoring programme was established and a team from the United Nations Environment Programme visited at the request of SEPA to help with mitigation and assessment.

In this incident, it took several weeks for the chemical pollution to cross international boundaries; however, chemical releases that occur where countries are in close proximity result in pollution quickly entering neighbouring countries. In such cases, a pre-existing international response plan is an important and necessary element of successful remedial action.

This incident also highlights the mechanisms developed by the international community (represented in this case by the World Health Organization and the United Nations Environment Programme) to provide support to countries following chemical incidents. A nation's Chemical Emergency Response Plan should reflect that this assistance can be called upon during or after chemical incidents.

KEY POINTS

- Because the releases from many chemical incidents can cross international boundaries, communication channels between neighbouring nations should be established as part of a preparedness plan, particularly where countries are in close proximity.
- International organizations have the potential to facilitate communication between countries. The International Health Regulations 2005 (see section 2.4.1) provide a notification and alert system for public health events of international concern.

CASE STUDY 9: ILLEGAL DUMPING OF TOXIC WASTES IN THE CITY OF ABIDJAN – CÔTE D'IVOIRE

In the late hours of 19 August 2006, a ship named *Probo Koala* offloaded up to 500 tonnes of wastes for disposal in the city of Abidjan, Côte d'Ivoire. The wastes were rumoured to be dirty water for cleaning the ship's gasoline tanks and were handled by an Ivorian company created a few weeks earlier. During the night, the wastes were dumped at more than 20 sites around the city.

Soon after, the local population started experiencing nosebleeds, nausea, headaches, skin and eye irritation, as well as respiratory problems. The number of people complaining about health problems led to an investigation that showed that the wastes offloaded by the *Probo Koala* were in fact composed of acutely hazardous chemicals such as hydrogen sulfide, mercaptans and sodium hydroxide.[a]

Local health care centres were soon overwhelmed by people seeking treatment. The sudden inflow created widespread disorganization of the health services and generated a shortage of medical supplies. On 25 September 2006, the crisis had led to eight deaths, 68 hospitalizations and more than 77 000 hospital consultations.[b]

In an attempt to help the Ivorian government manage the health care aspects of the crisis, experts from the United Nations and the World Health Organization were sent to Abidjan. They assisted in coordinating the health response by contributing to the evaluation of risks posed by the chemicals, providing information to the public, preventing further exposure, and forwarding medical supplies to the country. Simultaneously, a French team was sent to the country to secure the hazardous sites and address waste clean-up.[c]

The toxic waste crisis in Côte d'Ivoire was the result of weak implementation of environmental regulations and controls as well as corruption. This combination enabled the wastes to be handled by an Ivorian company without any particular expertise in management of hazardous chemicals. It was overall a reminder of the importance of countries implementing and enforcing the Basel Convention, which aims to prevent transfer of hazardous wastes across national borders, particularly to developing countries.

KEY POINTS

- The implementation and enforcement of international conventions such as the Basel Convention is an important step in preventing the transfer of toxic wastes into countries that do not have the infrastructure necessary to treat chemical products.
- Environmental regulations and controls are important to detect potentially hazardous materials and ensure that they are properly handled.
- A system to detect a chemical incident by a sudden influx of patients should be in place.
- A preparedness plan should take into account the possibility of a sudden influx of patients into health care centres.
- Good public communication is necessary to promote an effective and risk-avoiding population response and enhance confidence in the local and national government agencies. These aspects should be considered in the preparedness plan.

[a] World Health Organization. *Déversement des déchets toxiques en Côte d'Ivoire* (http://www.who.int/mediacentre/news/notes/2006/np26/fr/index.html).
[b] United Nations Office for the Coordination of Humanitarian Affairs. Situation Report no 10. *Crise des déchets toxiques/toxic wastes pollution crisis, Côte d'Ivoire* (http://www.reliefweb.int/rw/RWB.NSF/db900SID/KKEE-6U2PVT?OpenDocument).
[c] Actualités des Nations Unies à Genève. *Le Blog de la Mission de France. Côte d'Ivoire : les déchets toxiques seront traités en France* (http://www.delegfrance-onu-geneve.org/blog/index.php?2006/11/06/150-cote-divoire-les-dechets-toxiques-seront-traites-en-france).

coordinated communication programme is especially useful. A good way to implement such a programme is to use the ICS. In the preparedness stage, a system for public crisis communication can be designed and tested. This includes plans, procedures, command-and-control, designation of spokespersons and standard messages for possible scenarios. Guidance on crisis communication is available.[1,2,3]

[1] US Department of Health and Human Services. *Communicating in a crisis: risk communication guidelines for public officials* (www.riskcommunication.samhsa.gov/index.htm).
[2] Health Canada. *Crisis/emergency communications guidelines* (http://www.phac-aspc.gc.ca/sars-sras/cecg-ctcu/hc-cecg.pdf). The Peter Sandman risk communication website. *Crisis communication: guidelines for action* (www.petersandman.com/handouts/AIHA-DVD.htm).
[3] World Health Organization. *Effective media communication during public health emergencies* (www.who.int/csr/resources/publications/WHO_CDS_2005_31/en/).

3.6 BUILDING HUMAN CAPACITIES

Chemical incident exercises are necessary at both the national and local levels. The exercises should be facilitated by a coordinating organization that also provides training materials. Planning (and rehearsals) helps to ensure that people have developed, understood and learned their roles before any incident occurs. It is important to have methods to audit or evaluate the exercise to identify gaps in services and to monitor the effectiveness and efficiency of local multi-disciplinary public health groups. A thorough evaluation, or audit, of the plan, infrastructure, capabilities and their implementation should be carried out after every incident or training exercise. Incident audits provide valuable lessons on which parts of an incident plan were successful and which parts need improvements. In addition to these activities, it is very important to ensure that parallel efforts are made in educating managers to deal with issues such as human resources, conflict and logistics management, clear lines of command, and control and communication skills.

3.6.1 Training

Establishing a routine training programme and participating in exercises are essential components of preparedness and response to chemical incidents. Minimal requirements for the routine training programme should be developed so that the training is standardized and harmonized across the country and conforms to national standards. The local teams should be trained to respond properly to situations that might become chemical incidents and should learn how to respond to an actual chemical incident to minimize risks for workers, responders, the public, and the environment.

Individuals and organizations with specific responsibilities in situations requiring a response to a chemical incident should receive joint theoretical and practical training in the use and implementation of emergency response plans appropriate for the chemical incident. Proper coordination and communication will enable responders to become familiar with the broad cooperative effort required to respond to a chemical incident. It is vital that those with responsibilities in the event of a chemical incident know one other, become familiar with one another's procedures, recognize the necessity of the other parties being part of the organization, and appreciate the other parties' roles and responsibilities and the difficulties in executing them. An effective training programme should also ensure that all the organizations involved are used to working effectively with one another.

Core training programme

Core training for the local response team is an important mechanism to enable staff from all organizations to gain a basic understanding of their own and of others' needs and expertise. The core training programme should be designed to include informational, procedural and hands on elements. It is essential that these training programmes are provided regularly so that individuals stay informed about key components of the incident response programme, as well as receiving updated information regarding new technologies and changing potential hazards. Public health elements that should be included in the core training include:

- environmental chemistry, fate and persistence
- common symptoms associated with chemical exposures
- epidemiology and toxicology
- risk and exposure assessment
- emergency actions and procedures to reduce risk to both responders and the public
- proper use and limitations of protective equipment
- shelter and protective measures
- biological and environmental sampling
- key components of a control system for a major chemical hazard
- risk communication techniques
- local chemical sites.

Community impact assessment programmes, discussed in section 3.3, should be seen as an opportunity to involve local individuals and communities with little experience in epidemiology, toxicology, and environmental assessment so that the expert colleagues are helping the less well-informed individuals and community members to understand the incident response. Other public health functions, such as establishment of a surveillance system, can also provide training opportunities. The following sections outline key components of an effective training and emergency preparedness programme.

3.6.2 Exercises

Staff will require specialized training in relevant, core areas. Countries should review the best ways to establish access to comprehensive training for all those public health and environmental health professionals who may have responsibilities for responding to chemical incidents. This could be organized through public health training centres, poison centres, national information and advisory centres, or local response units.

It has been clearly demonstrated that the effectiveness of theoretical training is maximized by using exercises. Exercises are generally classified into three major categories: tabletop, functional, and full-scale simulations, and can be conducted as single discipline or multidisciplinary exercises. Individual agencies may also consider running preliminary orientation exercises to introduce participants to their responsibilities under the chemical incident plan, and to prepare them for the exercise process.

Orientation exercises

An orientation exercise acquaints staff with the policies and procedures in the chemical incident plan, providing a general overview of its provisions. It is especially effective in ensuring that personnel understand their roles and responsibilities and how to access background information and specialist advice. Orientation training also helps to clarify complex or sensitive elements of the plan. The orientation exercise does not generally involve any direct simulation, but is used to review plan procedures and informally apply them to potential emergency situations, preferably those involving local priority sites and priority chemicals. This type of training should be provided for individuals who are being introduced to a chemical incident response system for the first time, such as new employees.

Tabletop exercises

Tabletop exercises at the organizational level are more formally structured than orientation exercises, and often involve more than one sector with responsibilities under the chemical incident plan. Prepared situations and problems are combined with role-playing to generate discussion of the plan, its procedures, the resources that can be called upon, and the policies to be adhered to when making decisions. Tabletop exercises are a good method of familiarizing individuals and local groups with their roles and demonstrating proper coordination. They provide a good environment in which to reinforce the logic and content of the plan and to integrate new principles into the decision-making process. During these exercises participants should also be encouraged to discuss possible limitations of the response plan that they may have recognized through training or experience.

Participants are encouraged to act out critical steps, to recognize difficulties, to use the expertise of the other sectors represented, and to resolve problems. Tabletop exercises usually take two to four hours and require specially trained facilitators who are intimately familiar with the response system. These facilitators should be rotated from agency to agency so that responders become familiar with various styles of emergency response.

WEB LINKS 4: EXERCISES

For more information on incident exercises visit the UK Health Protection Agency at: http://www.hpa.org.uk/hpa/erd/erd_exercises.htm and the US Department of Homeland Security Exercise and Evaluation Program at https://hseep.dhs.gov/. For information on training courses visit the US Federal Emergency Management Institute at http://training.fema.gov/emiweb/IS/crslist.asp

Functional exercises

A functional exercise is an emergency simulation designed to provide training and evaluation of integrated emergency operations and management. More complex than tabletop exercises, functional exercises focus on full-scale interaction of decision-makers and agency coordination involving a typical incident coordinating centre. All field operations are simulated; information about activities is transmitted using actual communications equipment such as radio and telephone. Functional exercises permit decision-makers, off-site incident coordinators, on-site incident managers, as well as coordination and operations personnel to practice emergency response management in a realistic situation with time constraints and inherent stress. Such exercises generally include several organizations and agencies practising the interaction of a series of emergency functions, such as initial information gathering from the incident hotline, the make-up of the core team, direction and control of communications, and access to and mobilization of databases and specialists to provide advice, public warnings, and decisions on evacuation.

Full-scale simulation exercises

A full-scale simulation exercise focuses on multiple components of an incident response and management system simultaneously. It enables participants to experience the interactive elements of a community emergency programme in a similar fashion to the functional exercise, but with the addition of a field component. A detailed scenario and simulation are used to approximate an emergency which provides on-site direction and operations, and also includes coordination and policy-making roles at the off-site incident coordinating centre. Direction and control, mobilization of resources, communications, assessment, decontamination, treatment and triage, and other special functions are commonly practised.

Outcome and evaluation of exercises

Similarly to an audit of the response to an actual chemical incident, exercise audits will enable the chemical incident plan to be updated and improved, and allow training requirements to be identified. It is important that this audit system remain positive; it should not only focus on the strengths of the programmes, but should also identify shortcomings in a positive reinforcing way. Any audit should have a follow-up and should cover at a minimum the following three areas:

- Plans and procedures: 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 and with outside parties?
- Decisions: did the team reach the right conclusions and make the right recommendations, given the available information?

4 DETECTION AND ALERT

Some chemical incident scenarios (section 1.2.2) are self-evident due to their catastrophic impacts and potential to affect large populations. However, most acute chemical events are small to medium incidents that few people (perhaps only the polluter and the persons directly involved) are aware of initially. In many such cases, the polluter may fail to notify public authorities of a chemical release event. This may be because the polluter considers that the incident is minor and can be handled without outside assistance. However, in many cases the polluter does not have the appropriate knowledge and training to evaluate the potential risk from a chemical release. Other motivations may also prevent a polluter from notifying emergency or public health services, including not wanting to be identified, not appreciating or caring about risks to the public or to the environment or not wanting to cope with the financial consequences of the incident. A polluter may fear criminal or civil prosecution in response to a release. A chemical incident might have both short-term and long-term effects on public health, and the responders and public health authorities need to be able to recognize crises when they occur, so that their impacts can be assessed and minimized.

4.1 ESTABLISH METHODS TO DETECT CHEMICAL INCIDENTS

There are several ways that local emergency and public health authorities can identify a chemical release, including notification from the person(s) responsible for the chemical release, notification from the public of visible evidence of a release – such as what may be observed from an explosion – or notification of less obvious environmental or health changes such as dirty surface water, an airborne contaminant plume, death of wildlife or irritation of the eyes or nose. It should be noted that members of the public may often be very concerned when they perceive a potential environmental or health effect. Authorities should be aware of this concern and work to inform members of affected communities appropriately. Public communication is discussed further in section 5.6.

In addition to identifying chemical incidents from notifications by the public or person(s) responsible for a chemical release, there are several methods that can assist with detection of chemical incidents, including training in the recognition of chemical incidents for public health officials, medical professionals, first responders, and members of the community; population health surveillance; and environmental monitoring systems.

Once an incident is detected, trained authorities may respond appropriately to an incident, evaluate risks to public health and to the environment, and implement appropriate actions based on established guidelines and procedures. As an incident response progresses, national resources and expertise may be required to provide support.

Chemical incident recognition training

Members of the public health community including first responders, public health authorities, the medical community, poison control centres, epidemiologists, and other parties, such as responsible industry officials, should be trained to recognize potential chemical incidents and to respond appropriately to them. The components of this process require:

- Public health authorities, members of the medical community, and first responders should be educated to recognize chemical incidents so they can be alert for their occurrence and should also be educated so that they can respond appropriately.
- A well-publicized emergency telephone number and/or Internet contact information should be maintained twenty-four hours per day for use by the public health community, emergency response and other authorities (such as those responsible for water and food safety) and the general population to report chemical incidents to the appropriate authorities.
- Surveillance and monitoring systems should be in place that can provide quantitative measures of trends in environmental and public health data.

4.2 HEALTH AND ENVIRONMENTAL SURVEILLANCE

4.2.1 Population health surveillance

A major part of an effective toxic event management system is to establish a routine population heath surveillance programme at the most appropriate administrative level. This programme, which includes continuous and systematic collection, analysis, and interpretation of health data, should be maintained following the establishment of the baseline health assessment described in section 3.3 in order to:

- identify a health event that may be related to a chemical release;
- monitor trends in different types of population health indicators;
- stimulate epidemiological research that can lead to prevention or control; and
- evaluate the effectiveness of control measures.

The routine health monitoring programme should include regularly updated information on health statistics as well as regular updates on irregular health

CASE STUDY 10: DISEASE OUTBREAK DUE TO THE INADVERTENT USE OF AN INSECTICIDE IN THE PREPARATION OF SWEETS – BOHOL, THE PHILIPPINES

On Wednesday 9 March 2005, during their morning break, children attending the local elementary school in the city of Mabini purchased deep-fried cassava balls from a street vendor. Within minutes of eating the sweets, some of the children began to show symptoms of illness, including severe stomach pain, vomiting and diarrhoea. Before they could get to hospital, 14 of the children, aged 7–13 years, were dead. Another 13 died upon arrival at hospitals in the area. In total, 29 people died, and 104 more were hospitalized.

In this incident, the Department of Health worked with toxicologists at the University of the Philippines Poison Center to narrow down the cause of the outbreak, determine its origin and devise methods to contain the threat. Authorities initially suspected that a naturally occurring form of cyanide in cassava was the cause of the acute health effects. The types of symptoms exhibited, the low levels of cyanide in the bodies of the affected people, and the quick recovery of survivors when administered atropine, however, all suggested a neurotoxic agent other than cyanide. Four days after the outbreak, investigators recovered a partially used packet of a carbamate insecticide from the kitchen of one of the cassava vendors. Analytical chemical testing concluded that the carbamate insecticide, which is an odourless white powder, was inadvertently used in the preparation of the sweets in place of flour.

KEY POINTS

- All of the relevant resources available, such as poison centres, should be employed, during a disease outbreak to allow the cause to be quickly determined and the outbreak contained. Consideration should be given to the “causative party” of the outbreak (in this case the street vendor). The information provided is potentially helpful when piecing together the entire outbreak scenario.
- Means to detect and deal with outbreaks of disease as early as possible should be available. Hospital- and/or poison centre-based surveillance systems should be considered for detection of outbreaks.

events that may be indicative of a chemical release. Such information may be collected and analysed by governmental agencies at all levels, but should be stored in a database that is maintained by a single national organization. A routine health surveillance programme should also be designed to ensure simplicity, flexibility, acceptability, sensitivity, representativeness, and timeliness. The essential components of the routine health data monitoring system are discussed in the following sections.

4.2.2 General health statistics

Data from many sources (e.g. from censuses, hospitals, or disease registries) should be collected, organized, and presented in a way that allows effective analysis of trend and enables comparisons to be made. Collection of the data should therefore be practical, and the data should be accurate, comprehensive, up-to-date, and easily accessible to decision-makers. At the same time, it is important to be aware of the limitations of the individual data sources. Also, because the health data are likely to be collected from many different populations and by various people, it is important to ensure that the data and the collection methods are consistent. Common sources of data are listed below.

Censuses

Quantifying and defining the population is essential for evaluating rates of incidence and exposures. National censuses are routinely conducted in many nations. However, migration and changes in birth and death rates, as well as the frequency with which census data are collected, can have a significant impact on the reliability of census data. Routinely collected census data can be used to establish baseline statistics that can then be used to coordinate and marshal resources during a chemical incident. Census information may also provide governmental agencies with vital information for planning purposes.

Mortality rates

Most countries have programmes for registering deaths, often with information about causes of death. Coding death certificates using the International Classification of Diseases (ICD)[1] system allows for standardization of the reporting; however, the ICD is often not very helpful for chemical incident reporting because it does not classify diseases by all chemical causes. Mortality data may be useful for retrospective studies or for an evaluation of chronic exposures. A potential limitation of these data is that inaccuracies can occur due to human error. Human error can occur at various steps in the data collection process, ranging from making clinical diagnoses and completion of the death certificate; through transcription of this information on to the death notification together with its classification and coding; to the processing, analysis, and interpretation of the resulting statistics.

Hospital admission data

In many countries, hospital admission data are a good source of information about illness and disability. Usually, however, patient data are not specific to geographical areas, but rather to the hospital location. In addition, disease data are normally reported by using the ICD (see above) which does not allow for the full classification of disease by chemical cause. For health conditions of particular concern, the population admission rates will need to be calculated by searching the records of all hospitals that may have treated patients with similar clinical symptoms. Routine updating of hospital admissions data may provide critical information in response to chemical incidents. Abnormal spikes in hospital admissions may indicate the occurrence of an acute event that will require an appropriate governmental response. Treatment regimens which may be indicative of certain health effects or exposures could also be valuable indications of accidental or non-reported chemical events. It is therefore vital that health care professionals are trained to recognize these signs and to respond accordingly.

Other health care services

Data can also be obtained from outpatient services, private practice, accident and emergency, and other

[1] *World Health Organization international statistical classification of diseases and related health problems*, 10th Revision, Version of 2007 (http://www.who.int/classifications/apps/icd/icd10online/).

primary care facilities. Summary data routinely reported by private groups provide valuable information that may be used for managing chemical incidents. Unfortunately the data available from these sources may not be standardized among countries and may also be variable within countries. It is therefore important to establish standardized procedures for entering data into a tracking database, to facilitate rapid coordination among health professionals in the event of a chemical incident.

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. This information is important in retrospective analysis. However, there are significant limitations in using cancer as a potential end-point for environmental health assessments in managing current and future chemical incidents. Specifically, there is a long latency between exposure and disease onset (typically of 20 years or more), and this is usually compounded by a lack of accurate information on exposure for individuals with cancer. Also, it may be difficult to track individuals for 20 years or more. In addition, cancers may have multiple etiologies or else the etiology is poorly understood. Nonetheless, local and national cancer registry information may still be useful in evaluating the long-term public health issues facing national governments.

Congenital malformations registers

Population based registers at both the local and national levels have been established in some countries to foster research into the causes of congenital malformations and to detect changes in prevalence rates of congenital malformations. Experience in the use of these registers, however, has shown that recognition and registration of malformations is time consuming, and it is not feasible to use them to identify chemical incidents. These registers may be more useful for retrospective assessment of the population health effects following known incidents of exposure, in which case it will be necessary to link new entries in the congenital malformation register with the population of exposed people.

4.2.3 Sentinel health events

A sentinel health event is the observance of a preventable disease, disability, or untimely death whose occurrence serves as a warning signal that a hazardous environmental exposure may have occurred or may be in the process of occurring. As part of health surveillance and reporting (e.g. by a poison centre), the main purpose of monitoring local sentinel health events is to identify chemical releases that have gone unreported or unnoticed as was the case in Panama (section 4), page 53, or where releases had been thought to be harmless. Once identified by local authorities, the sentinel health event is useful to identify the need for:

- further epidemiological or environmental studies;
- engineering or other control measures to eliminate a hazardous exposure pathway, be it environmental, food- or water-borne;
- preventive measures by which local agencies can reduce the likelihood of a particular incident; and
- preventive care and treatment for the sentinel individuals and others.

The personnel involved in local chemical incident response can work within communities to identify diseases associated with priority chemicals in their area. A list of early warning signs can then be developed for local communities. A routine medical evaluation of local workers might also enable the public health authorities to detect unusual acute and/or long-term health effects associated with unnoticed chemical incidents. Depending on feasibility and importance to the local community, a sentinel events reporting system can also be established. After an incident has occurred, specific clinical reporting systems for sentinel health events can be established around sites of contamination at the local, regional, or national level using routine reporting systems such as death certificates or cancer registers. This follow-up monitoring may be important for tracking potential effects of the chemical release incident in an affected population during a chemical incident and over time. Local poison centres might play an important role in contributing to these activities.

4.2.4 Challenges for population health surveillance systems

There are several potential challenges that may arise during implementation or maintenance of population health surveillance systems at different organizational levels. Some challenges that chemical emergency managers may encounter include lack of data, inaccurate data, errors associated with data analysis, disorganized data, insufficient resources, confidentiality issues, and the diverse and often conflicting interests of different reporting agencies. Coordination among local authorities which typically collect the data, regional authorities which summarize or manage the collected data, and national agencies which analyse the data should be maintained to ensure that surveillance systems are in place and operational when a chemical incident occurs.

4.2.5 Environmental monitoring

As was shown by the Songhua river incident in China (section 3), page 41, a major component of an effective chemical incident management system is the establishment of a routine environmental monitoring programme in high-risk or densely populated areas. This programme should include periodic measurements of chemical concentrations in various exposure media (i.e. water, soil, air or foodstuffs) in areas surrounding potential sources of chemical release, such as industrial sites. This programme, which comprises ongoing and systematic collection, analysis, and interpretation of environmental data, is important for several reasons, including, but not limited to, the following:

- to provide data on background levels of chemicals in environmental media;
- to demonstrate any normal variation in those levels;
- to act as a warning when a sudden increase in chemical concentration is detected;
- to enable comparison with levels following a chemical incident; and
- to determine restoration to background levels.

Routine environmental monitoring programmes should focus on evaluating concentrations of chemicals of potential concern in a variety of environmental media. Specifically, potential contamination of air, water, soil, and food crops should be evaluated in the vicinity of chemical plants and monitored for the range of chemicals being manufactured, used or stored, as well as degradation products of those chemicals. The goal of the environmental monitoring programme is to establish baseline concentrations of chemical compounds that can be used as a basis for comparison if concentrations increase following a release. Therefore, to ensure that baseline data are representative of normal conditions, environmental sampling data will need to be updated regularly, at intervals depending on the anticipated fluctuations of the contaminant in the local environment.

Conducting environmental measurements is important and requires well-equipped and skilled personnel to carry them out. Proper training is critical. To ensure that environmental sampling is done consistently and in a valid manner, a standard operating procedure (SOP) should be developed that contains protocols for sampling methods. The SOP is described in Box 5.

BOX 5: STANDARD OPERATING PROCEDURE FOR ENVIRONMENTAL SAMPLING

The aim of the standard operating procedure (SOP) is to ensure that data are collected consistently and in a valid manner. The SOP should either identify accredited laboratory facilities that have the capability to perform quality control procedures, or should identify criteria for selecting such laboratories.

A SOP should also contain information on how to develop a systematic collection plan for the areas to be sampled. Prior to sample collection, many factors should be considered, including sampling duration, frequency, methodology, and comparison of concentrations with control samples. Also, environmental measurement techniques should include the following considerations for the contaminants being measured:

- **representativeness**
- **independence**
- **precision**
- **accuracy.**

Although environmental sampling provides critical information, all environmental sampling techniques have limitations. It is important to understand and take into account these limitations, such as the lowest level of a certain contaminant that can reliably be quantified or interferences from the matrix in which the pollutant is measured prior to implementation of a monitoring programme. Other common limitations include the fact that many measurement techniques involve use of monitoring equipment that can be influenced by factors such as temperature and humidity. Certain quality control procedures,[1] such as collecting replicate and blank samples, can reduce sampling errors. These matters should be part of the routine environmental monitoring quality assurance and control plan.

[1] United Nations Environment Programme, International Labour Organization and World Health Organization. *Environmental Health Criteria 214, Quality Assurance and Quality Control* (http://www.inchem.org/documents/ehc/ehc/ehc214.htm#SectionNumber:11.2).

A common, but not insurmountable, limitation of environmental monitoring is its cost. Monitoring equipment can be expensive, and both maintenance costs (e.g. for instrument calibration) and laboratory analytical costs, can be high. However, since it is important to ensure that the results of environmental monitoring are valid, it is often difficult to avoid high costs associated with environmental sampling. Two strategies, described below, are possible for analysing samples to ensure that they are valid at the time of an

CASE STUDY 11: MASS-ENDOSULFAN POISONING – JABALPUR DISTRICT, INDIA[a]

On 14 January 2002, a mysterious illness was reported from Amarpur, a small village with a population of 600, located near Jabalpur, India. The illness had started with two children, and before long, most of the members of six families in the village were suffering from symptoms ranging from moderate to severe vomiting, dizziness, turning of the eyeballs and abnormal movements of the limbs, which were followed by unconsciousness. Suspected to be possessed by bad spirits, the affected villagers were given no medical treatment, and three children aged 3, 5 and 15 years died within the first week. During the second week, some of the sick villagers were admitted to the district hospital, where they fully recovered. However, the convulsions started again when they returned to their homes. In the third week, 10 people were admitted to the medical college hospital situated in the nearby city.

On 13 February 2002, a team of public health professionals was sent to visit Amarpur. The team gathered information from various sources, ranging from discussions with the villagers and the hospital physicians to examination of the medical records of the 10 hospitalized individuals.

The clinical course of the illness and the observed patterns of use of pesticides by the villagers soon led the public health team to suspect a mass-poisoning with a pesticide widely used in India, endosulfan. With the consent of the parents or patients, blood samples were collected from eight of the hospitalized patients. Some food samples were also collected for analysis.

Very high levels of mass-endosulfan (i.e. 676 ppm) in a sample of *laddu* (a sweet made from wheat flour) and traces (3.98 ppb to 25.68 ppb) of endosulfan sulfate in the serum of the patients confirmed the diagnosis of endosulfan poisoning. All persons affected belonged to one of the six families who worked as farm labourers and obtained their food grains from a common source. Due to ignorance and extreme poverty, these people often used empty pesticide containers in the kitchen.

KEY POINTS

- Empty pesticide containers are often reused by illiterate and poor workers in developing countries. To prevent accidental poisoning, the pesticide industry and policy-makers must strictly enforce regulations on proper use of these products.[b]
- Health facilities often lack the analytical facilities required to diagnose an illness of chemical origin, which can lead to life-threatening delays in treatment. Even though supportive care is often the most significant part of medical treatment, it is essential that health professionals receive proper training on how to recognize these illnesses.
- Any unusual rise in a type of illness in a localized community or in hospital admissions should be recorded and investigated.

[a] Dewan A. et al. Repeated episodes of endosulfan poisoning. *Journal of Toxicology, Clinical Toxicology*, 2004, 42:363–369.
[b] *WHO/FAO Guidelines on management options for empty pesticide containers*. World Health Organization/Food and Agriculture Organization of the United Nations, 2008 (http://www.fao.org/ag/AGP/AGPP/Pesticid/Code/Download/Containers08.pdf).

incident. The second option can help reduce the high costs of laboratory analysis:

1. Analyse all the samples at the time of collection for the full range of contaminants that might be encountered in a local incident. Costs can be high, but data could also be used by other agencies, for other purposes. Hence, the total cost could be shared among other agencies and local communities that might also want to use the data.

2. Store samples and only analyse them following a chemical release incident and only analyse them for those contaminants that are of interest. Using this strategy can minimize costs. However, some samples can only be stored for a limited time and this must be taken into account to ensure that the samples collected remain valid. If this strategy is used, storage has to be overseen and guidance given to personnel to ensure consistency and proper care of the samples.

Another important mechanism to control costs is study design. Local input into the study and sampling design may provide cost-effective alternatives to enable the sampling goals to be achieved at minimal costs. In many countries, public health authorities may wish to enlist specialists who have experience with the principles and methods of environmental monitoring. Officials representing national authorities may provide invaluable assistance in coordination of monitoring efforts.

4.3 ALERT CHANNELS

Once a chemical incident is detected by the channels described in section 4.1, it is essential to mobilize appropriate local and regional public health, environmental and incident management personnel and equipment as quickly as possible. This is especially important because in many cases, the people who initially respond to an incident (such as local police or other emergency services) may not be adequately trained or equipped to recognize or address potential risks associated with an incident.

Additional components of the process of alerting the public health and other members of the chemical incident management organization are described in section 5.4.

BOX 6: WHEN SHOULD A CHEMICAL INCIDENT ALERT BE ACTIVATED?

A chemical incident alert should be activated if:

- **Notification of a chemical release is provided by the person(s) responsible for the release**
- **Notification regarding visible evidence of a release (explosion, environmental changes) is provided by the public**
- **The surveillance and monitoring systems show warning signals such as the occurrence of a sentinel health event or a sudden increase in levels of a contaminant in the environment.**

CASE STUDY 12: MASS POISONING DUE TO THE PRESENCE OF DIETHYLENE GLYCOL IN COUGH SYRUP – PANAMA

In early September 2006, the personnel of Panama City's big public hospital noticed a surprising number of patients exhibiting the same unusual symptoms. At first, these patients were diagnosed as suffering from a relatively rare neurological disorder, Guillain–Barré syndrome. However, the appearance of new symptoms and the increasing number of cases soon made this hypothesis unlikely. The doctors at the hospital sought help from an infectious disease specialist.

The group soon reached the conclusion that the hospitals in Panama City were being confronted with the outbreak of an unknown disease, whose death rate was close to 50%. As a precaution, the affected patients were segregated into a large room and health care workers were requested to wear masks. As local health care services became overwhelmed, similar cases in other parts of the country were reported.

After several days, the team's attention was caught by a cough syrup, whose use had at first not been reported by some patients because it was such a common product in their lives. The investigators of the United States Centers for Disease Control, who were in Panama helping out, took the syrup to the US for analysis. The result was unambiguous: the cough syrup contained diethylene glycol, a highly toxic chemical normally used as an industrial solvent and as an ingredient in antifreeze. Its sweet taste makes it a cheap counterfeit for glycerine, a chemical commonly used in medicines, food, toothpaste and other products. An investigation[a] conducted by the *New York Times* later showed that the counterfeit glycerine had been sold by a company as 99.5% pure glycerine, and had unknowingly been used to prepare 260 000 bottles of cough medicine.

A nationwide campaign was quickly launched to stop people from using the cough syrup. Neighbourhoods were searched, but thousands of bottles had either been discarded or could not be found. The exact number of deaths caused by consumption of the cough syrup is not known, but at least 100 fatalities have been confirmed so far.

KEY POINTS

- Chemical incidents are often responsible for outbreaks of illnesses with unusual symptoms. The appearance of sentinel events should be notified to the agency in charge of the management of chemical incidents and should trigger an alert.
- International cooperation can help in identifying the source of the outbreak more quickly.
- Medicines should be subjected to stringent inspection procedures before being distributed.

[a] From China to Panama, a trail of poisoned medicine. *New York Times*, 6 May 2007.

5 RESPONSE

Following the occurrence of any chemical incident, there are a number of essential steps that must be taken in order to respond effectively to the incident. The initial alert steps are described in section 4, while the response steps are described in this section.

The major steps that should be taken during a chemical incident include the following:

1. Terminate the release, prevent spread of the contamination and limit exposure.
2. Activate the incident management system, including a public health response.
3. Provide an initial assessment and advise and alert the health care services.
4. Ensure coordination and integration of the public health response.
5. Conduct a best outcome assessment for both immediate and long-term actions.
6. Disseminate information and advice to responders, the public, and the media.
7. Register all exposed individuals and collect samples to eliminate exposure.
8. Conduct investigations.

5.1 TERMINATE RELEASE, PREVENT SPREAD OF CONTAMINATION AND LIMIT EXPOSURE

The role of public health in the termination of release might differ depending on the scenario. In the case of an incident at a chemical plant, for example, the actual termination of a release is usually a combined effort by company personnel and emergency services familiar with responding to events involving toxic products (e.g. the fire brigade's hazardous materials specialists). This usually requires specialized equipment and personal protective equipment (PPE) for the personnel involved. However, in the case of an outbreak, the public health community usually plays a critical role in detecting the incident, identifying the nature and source of the contamination and in the termination of exposure (e.g. by withdrawing products from the market).

Public health can play a role in setting priorities by making rapid assessments of possible alternative courses of action (e.g. extinguishing a fire or letting it burn out). Such decisions may also affect the spread of the hazardous chemical.

Public health roles in the prevention of spread include making rapid assessments of incident control options and contributions to decontamination, zoning and personal protection. These will be described briefly below.

WEB LINKS 5: CHECKLISTS

For checklists and other information on responding to acute hazards, visit the UK Health Protection Agency's Checklists for Chemical Incident Management at http://www.hpa.org.uk/chemicals/checklists.htm and the US CDC's Public Health Emergency Response Guide at http://www.bt.cdc.gov/planning/pdf/cdcresponseguide.pdf

A major role of public health is to assess the possible short- *and* long-term exposure and the related health risks through all possible exposure routes in support of immediate and long-term responses. Often the focus of the emergency response may be solely on one contact medium (such as air for releases of volatile substances), while secondary exposure routes may also contribute significantly to the health consequences (e.g. through contamination of crops).

Decontamination

Decontamination removes the hazardous substances from the victims, the responders and their PPE, and the equipment and vehicles at the site of a chemical incident. The aims are to prevent movement of hazardous substances from contaminated into clean areas, to protect the public and downstream responders from exposure by secondary contamination, and to protect emergency responders by decreasing the chemical stress on their PPE. Decontamination can be effective to some extent even without exact knowledge of the chemical, and may need to be repeated before entry of contaminated people into a health care facility.

Public health can play an important role in deciding whether decontamination is required, for which individuals and equipment it is necessary, and how it should be carried out.

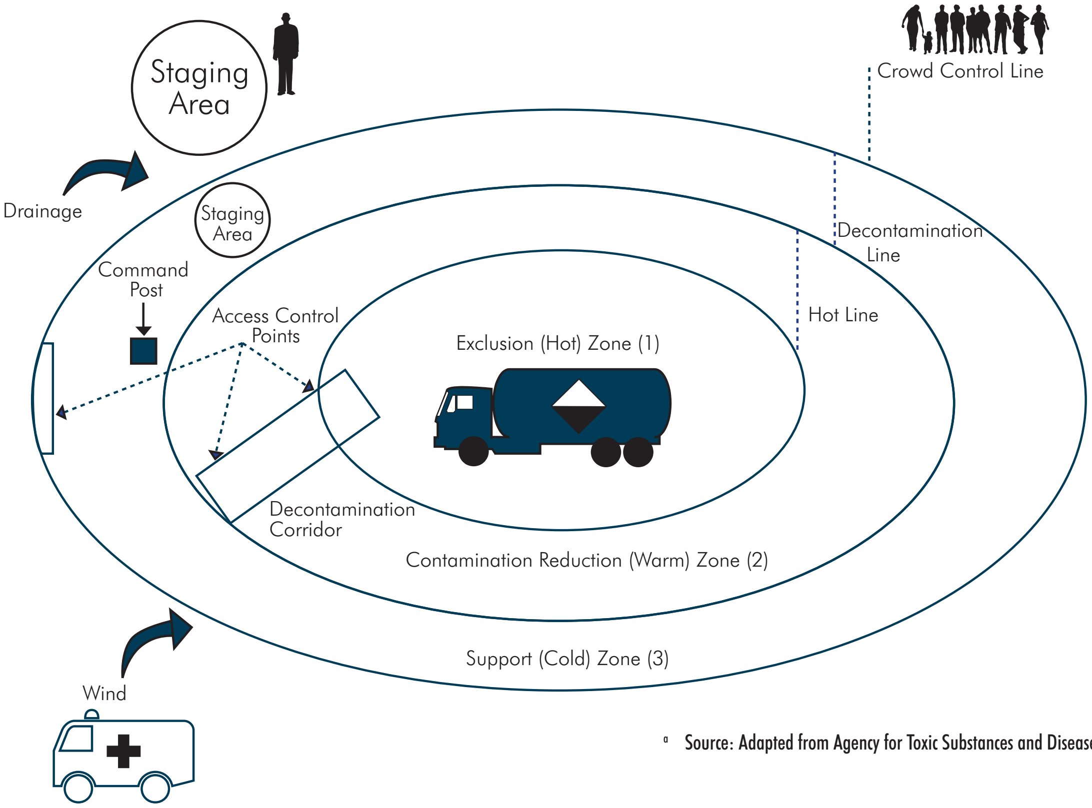
Chemical incident control zones

In many countries the incident area is divided into three zones,[1] establishing access control points, and delineating a contamination reduction corridor (Figure 8 below).

1. The Exclusion (Hot) Zone extends far enough to prevent primary contamination of people and materials outside this zone. Primary contamination can occur when individuals enter this zone. Usually, no decontamination or patient care except evacuation is carried out in this zone.
2. The Contamination Reduction (Warm) Zone is the area around the hot zone and contains decontamination corridors where victims, emergency responders and equipment are decontaminated, and where there is a risk of secondary contamination from objects/individuals brought from the hot zone.

[1] *Managing hazardous materials incidents.* Agency for Toxic Substances and Disease Registry, 2001 (http://www.atsdr.cdc.gov/MHMI/index.html).

FIGURE 8: CHEMICAL INCIDENT ZONING[a]



[a] Source: Adapted from Agency for Toxic Substances and Disease Registry (ATSDR) 2001.

3. The Support (Cold) Zone should be clean, meaning it is free of all contamination by hazardous materials, including discarded protective clothing and respiratory equipment. Contaminated victims and emergency response personnel must be decontaminated before entering this zone.

The command post and staging areas (see also section 3.4) for necessary support equipment should be located in the Support Area, upwind and uphill of the Exclusion Zone. Access to the different zones should be tightly controlled and limited to as few people as possible. Communication between work areas should be face-to-face whenever possible, particularly if the use of radios or other electronic devices (e.g. megaphones) is restricted because of the hazards involved.

Limit exposure

Protection of the public from chemical incidents follows general rules of public health prevention. In this section, the focus will be on primary preventive measures. The most effective primary prevention is to avoid exposure by avoiding or restricting intake of contaminated food, water, air or other contact media. For emergency responders, PPE is a viable option, while its use is complicated for the public. Another exposure-limiting approach is decontamination of contaminated individuals. If a population is at risk from an acute airborne release, two main options are available depending on the particular exposure conditions: either shelter in-place or evacuation/removal. Medical treatment is a last resort if all prevention fails. The following sections give a brief overview of some of the possible measures.

Personal protective equipment[1] (PPE)

PPE can be an effective way to reduce exposure, and includes chemical protective clothing including gloves and respiratory protection. Depending on the level and routes of anticipated exposure, different PPE is required. For a responder working at the source of a release, personal protective equipment such as impermeable clothing and full respiratory protection (level A) may be required, while for others splash-resistant clothing and an air purifying device may suffice. Working in the most protective PPE puts a considerable strain on the wearer (temperature, enclosure, impaired vision and communication), and significantly limits manual dexterity. The objectives of PPE use are always twofold: prevention of chemical exposure for the wearer and prevention of injury to the wearer from the PPE itself. The use of PPE requires training and exercise of the wearers, and precludes the use of some PPE by untrained individuals.

Shelter in-place (SIP)

For the public, the most desirable protective measure is sheltering in-place (i.e. staying indoors, closing all the windows and doors, and shutting down any ventilation or air-conditioning systems) until the chemical (usually in a cloud) has passed ("go in, stay in and tune in"). Depending on the air-tightness of the building, this procedure will usually provide a significant reduction of the concentration of a chemical indoors (compared with outdoors) for some hours in residential buildings in industrialized countries, which is adequate for many incidents. The level of protection given depends on the concentration outdoors. Dwellings in many less developed areas of the world may offer significantly less protection, if any, as was demonstrated when methyl isocyanate gas was released in the Bhopal incident. It should also be noted that this option is not always feasible, especially in tropical countries, where housing is usually open.

There may be risks to using in-place sheltering during an incident. For example, the public could be placed at risk if the chemical does not disperse as quickly as anticipated. People in houses will then either need to be evacuated (while the chemical plume still exists, creating a greater hazard) or provided with additional support (e.g. food, water and health care) which may be almost impossible in practice.

[1] *Managing hazardous materials incidents.* Agency for Toxic Substances and Disease Registry, 2001 (http://www.atsdr.cdc.gov/MHMI/index.html).

If people have been ordered to shelter-in-place, the moment when it is safe to leave and ventilate the shelters should also be communicated very clearly.

Evacuation/removal

Evacuation means removing people from the area of (likely) contamination into an area of safety (or relative safety). Evacuation will often involve complex logistics, including the provision of transportation; and shelter, food, water, and appropriate medical care (for pre-existing conditions, as well as health effects from chemical exposure) in the evacuation area. The security of the abandoned areas should also be considered. These logistic issues and the time required to implement an evacuation should be part of the emergency evacuation plan, if such a plan exists.

If the exposure is highly hazardous and evacuation is chosen as the best method to minimize health effects, then it must take place as quickly and in as orderly a manner as possible. Rapid evacuation poses some risks, mainly related to moving large numbers of people. These risks include falls, traffic accidents, lost children, and health disruptions for sick, elderly or otherwise disabled people. During a typical acute incident with airborne exposure, evacuating more than one thousand people is generally not feasible for those immediately threatened.

Deciding whether to evacuate or to shelter in-place

Assuming that both options are feasible, the decision to evacuate or to shelter in-place must be based on a balance of the risks associated with the two options. The primary consideration is the risk of both the exposure level and the exposure duration. A secondary consideration relates to the intrinsic risks of moving large numbers of people.

Evacuation is the better option when:

- The area is not yet exposed, but will be after a certain time e.g. due to an anticipated shift in wind direction (the time to exposure being longer than the time required for the evacuation).
- The likely duration of exposure is such that the protection offered by in-place sheltering may become insufficient.

Evacuation may also be the better option if:

- The chemicals are widely dispersed and contamination is extensive and persistent.
- The chemicals are suspected as being hazardous, but cannot be identified readily.
- The chemical is highly hazardous.
- The concentration in the air will be hazardous for a prolonged period.
- There is a risk of explosion.
- Number evacuees is relatively small.

Return

The decision to authorize return following an evacuation depends on availability of environmental monitoring data or other data adequate to support the conclusion that an area is safe, and the ability to provide adequate essential services. Supporting documentation regarding safety of the affected area and ability to provide essential services should be provided to decision-makers to ensure that they are fully informed before they make such a decision.

Other restrictions

Restrictions may be placed on access to contaminated areas as well as on consumption of contaminated drinking-water or food supplies. For example, it may be possible to restrict movement through an area where the soil is contaminated, to keep people upwind of a site where the air is contaminated, or to keep them away from any plume of smoke or dispersion cloud. Other measures may include controlled distribution of, or restricted use of, contaminated crops or livestock, or drinking-water supplies. If groundwater is contaminated, monitoring and/or modelling should be carried out to ensure that the contaminant has not dispersed into previously safe water supplies. In cases where there are restrictions on consumption of drinking-water or food supplies, public health officials should consider providing alternative supplies. When environmental contamination is not considered a health threat, but water or food supplies are contaminated, supplying uncontaminated products may be preferable to evacuation.

5.2 ACTIVATE PUBLIC HEALTH RESPONSE

5.2.1 Activating a response

As discussed in section 3, the response to a chemical incident will be most efficient if a documented plan and communications programme is available. The outline and general requirements for establishing a plan, funding necessary personnel, equipment, and other resources will normally be provided at the national level. The detailed activation plan and establishment of responsibilities and coordination following an incident would typically be established at the regional or local level, if appropriate and feasible in the country. However, the national level or lead chemical incident management agency should concur with each of the detailed local plans to ensure consistency and to be made aware of any potential outcomes based on what each community has deemed necessary for itself.

5.2.2 Advising and alerting medical services

Once activated, it is essential for medical personnel to gather as much information as they can as quickly as possible in order to make an initial assessment of potential or actual risks to health and the environment. Well-trained public health or environmental health professionals should assess the extent of casualties, if any, and alert and activate the local (and regional or national) health care facilities, as necessary.

Activating medical resources or other emergency responders, such as decontamination teams, will involve providing these agencies with information about the nature of the chemicals, any precautions to be taken, and about secondary contamination and how to decontaminate exposed members of the public or staff as well as equipment if necessary. If the number of casualties is likely to prove too great for the local receiving hospital, additional hospital facilities further away will need to be alerted and given the same information. Therefore, it is important, when developing a local incident response plan, to evaluate the capabilities of medical care facilities that may be involved in treating individuals affected by a chemical release event. Also, it is important to coordinate with these facilities as part of the process of developing the plan through training sessions that will make them aware of the potential for their involvement.

5.2.3 Activating inter-agency communication

As far as possible, effective coordination between agencies should be planned and tested during the preparedness phase in order to ensure rapid notification and mobilization of the appropriate local and national governmental agencies. Besides local responders, organizations that need to be notified of an incident include:

- **Other governmental agencies:** These agencies may need to be notified in order to provide resources and capabilities to respond to a chemical incident. It may be necessary for these agencies to provide a sustained government response, which is sometimes required following a chemical incident.
- **International organizations:** Notification to the World Health Organization (WHO) is required under the International Health Regulations 2005 (IHR (2005)) (see also section 2.4) for all events that may constitute a public health emergency of international concern. For the purpose of notification and communication, the IHR (2005) has defined National IHR (2005) Focal Points as well as IHR Contact Points within WHO.
- **Neighbouring and other countries:** If the incident has the potential to affect a bordering country and other countries, these countries will need to be informed quickly. Establishing lines of communication with neighbouring countries and other potentially affected countries as part of the preparedness plan discussed in section 3 allows for the rapid dissemination of information across international lines.
- **Nongovernmental agencies:** Depending on the severity of the chemical incident, local and international nongovernmental agencies may be requested to provide additional assistance. Coordinating with nongovernmental agencies may be an effective way of maximizing resources in the event of a chemical incident.

- **The involved company/source:** Often the source organization has crucial information about the release and experience with the (health) management on a small scale.

5.3 CONDUCT AN INITIAL ASSESSMENT AND ADVISE STAKEHOLDERS

Proper risk assessment during an incident can be used to determine whether individuals or populations are likely to be exposed, and what the possible health effects of short- and long-term exposures might be. This assessment may be done by the emergency services for populations near the incident site, or the public health team for more distant populations.

The levels of exposure can, in general, be significantly different for the various types of people who may have been exposed following a chemical release. There are three main categories of people exposed during an incident and the difference between them should be considered when developing the response plan for an incident. The three main categories of individuals and their exposure experiences are:

- **Workers and other on-site individuals (e.g. contractors and truck drivers)**
  On-site individuals have usually been exposed through more than one pathway, such as inhalation of vapour and skin contact from splashing and clean-up.
- **Emergency services**
  The exposures of emergency personnel are likely to be dependent on their occupation. For example a fire officer may be exposed through drenched clothing; ambulance officers through secondary contamination; and medical staff through exposure from incomplete or improper decontamination of casualties. Exposures will be dependent on the type of PPE used by each individual.
- **The public**
  Exposure of the public can occur through air, water, soil, and foodstuffs (Figure 7, section 3.3).

To offer advice about protection, information is needed on the levels at which a particular chemical causes adverse health effects, and also about the probability of health effects in the specific situation. This requires similar information to that needed for the below-mentioned best outcome assessment (section 5.5), including information on the incident source and type of chemical released, the likely exposure pathways, and information from the databases about the type, frequency and severity of the health effects of the chemical, as well as on the exposure levels at which effects might be observed.

Possible sources of information for rapid assessment of health risks are described below. The risk assessment process is described in section 1.3.1.

Predictive models

Predictive models are used to identify potentially affected populations and to estimate evacuation requirements. ALOHA (Areal Locations of Hazardous Atmospheres) is one of the most commonly used accidental release models and is used worldwide for response, planning, training and academic purposes. ALOHA is intended for use during hazardous chemical emergencies and was designed to be easy to use. ALOHA can predict rates of chemical release from broken gas pipes, leaking tanks and evaporating puddles, and can model the dispersion of materials with approximately the same density as air as well as materials that are more dense than air (e.g. chlorine). Other models that can be used for heavier-than-air gases include the US EPA

WEB LINKS 6: MODELS

More information about several of the predictive and general purpose models can be obtained by visiting the US EPA at http://www.epa.gov/scram001/dispersion_alt.htm and http://www.epa.gov/emergencies/content/cameo/index.htm

A more extensive listing is provided by the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) Directory of Atmospheric Transport and Diffusion Consequence Assessment Models: http://www.ofcm.gov/atd_dir/pdf/frontpage.htm

DEGADIS model, the SLAB model, and the AUSTOX model. If the gases are lighter than air (e.g. ammonia), general dispersion models can be used.

Exposure monitoring

In addition to modelling assessments of exposure, actual samples should be taken if possible. Possible strategies are sampling of contact media (air, food, settled dust, or water) or biological substances (e.g. in blood, urine or hair). The sampling guidelines drafted and exercised in the preparedness stage should be used whenever possible. Public health has a role in directing the sampling effort to optimize its usefulness for risk assessment (instead of e.g. source identification).

Exposure guidelines

Many of the predictive models consider the acute exposure guideline levels (AEGLs), emergency response planning guidelines (ERPGs), chronic exposure guidelines, or other exposure guidelines.

The AEGLs are developed by the US EPA National Advisory Committee for Acute Exposure Guideline Levels. Their final values are published by the National Academy of Science's Committee on Toxicology. AEGLs are developed for five different exposure durations: 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. For each exposure duration there are three AEGLs depending on the expected severity of health effects. The Technical Support Documents of the guidelines identify the substance, its chemical and structural properties, animal toxicology data, human experience, existing exposure guidelines, the rationale behind the selected value, and a list of references. The AEGLs are intended primarily to provide guidance in situations where there may be a rare, typically accidental, chemical exposure involving the general public (including the elderly and children). Therefore, these exposure guidelines do not reflect the effects that could result from frequent exposure.

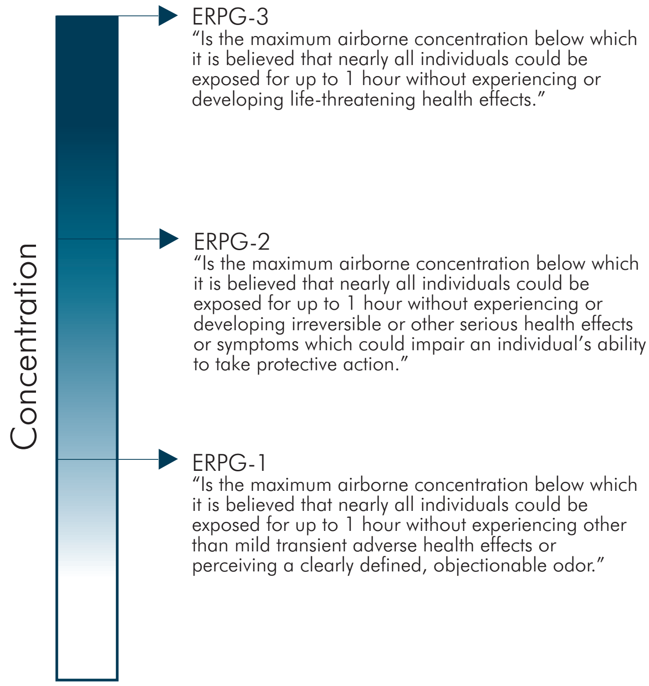
The ERPGs, developed by the American Industrial Hygiene Association, are airborne concentrations at which one could reasonably anticipate adverse health effects. Similar to the AEGLs, the ERPGs are a three-tiered system, based on severity of the health effects (Figure 9).

In any case public health and environmental professionals should first determine whether there are legally enforceable standards that apply to the situation. Other organizations may also provide recommended exposure levels that more appropriately apply to the situation. If it is determined that the

WEB LINKS 7: EXPOSURE GUIDELINES

For more information about AEGLs, visit
http://www.epa.gov/opptintr/aegl/pubs/chemlist.htm

FIGURE 9: THE THREE-TIERED ERPG PUBLIC EXPOSURE GUIDELINES[a]



[a] AIHA 2008. *Emergency response planning guidelines and workplace environmental exposure levels handbook*. Fairfax, VA, American Industrial Hygiene Association, 2008 (www.aiha.org). Used with permission of the American Industrial Hygiene Association (2009)"

situation is compatible with the conditions set by the AEGLS or ERPGs, the Technical Support Document (TSD) should be consulted first, which will require a decision regarding the relevance of AEGLs or ERPGs to the situation. AEGL and ERPG TSDs are designed to provide a justification of the derived numbers. Preferably, an abstract for operational application of these documents should be made available.

Verification

In all cases the results of the predictive models should be verified. Useful information for this purpose can be obtained for example from hospitals (admission data on transported or self-referred patients), complaint registrations from dedicated (e.g. environmental) hotlines, the observations of emergency personnel on- and off-scene and exposure monitoring. Such information is particularly useful when information on time and place is collected as well. Often the initial assessment of the chemical released and the quantity released prove to be wrong, and complaints do not seem to fit the alleged exposure. Any such verification strategy requires that the information collection and reporting mechanisms be prepared.

5.4 ENSURE COORDINATION AND INTEGRATION OF THE PUBLIC HEALTH RESPONSE

It is important to ensure that the response to the incident is consistent. With many people and agencies involved in the public health assessment, it is vital for advice to be channelled through one person in charge of coordination. One organizational (or management) tool that can be used to help coordinate a consistent and effective response to chemical releases is the incident command system (ICS),[1] described in detail in section 3.4.

Depending on the scale of the incident, the role of agencies with responsibility for the management of chemical incidents may range from mainly support functions to on-scene (mostly local) responses to chemical incidents. Examples of these support services may include laboratory facilities for identifying unknown chemicals, data collection and knowledge organizations such as agencies that compile weather data, which can be used for computer modelling efforts and which are often administered at the provincial and/or national level. In addition to these examples, a single organization (also often at the national level) is most likely to provide material resources or to assist in acquiring the necessary materials. It is therefore important that agencies involved in the local response communicate and coordinate effectively with their counterpart agencies at levels other than the local one to enable them to deliver the most appropriate materials, data, and advice.

In order for the response to a major chemical incident to be cohesive, the national government needs to be

[1] Some information regarding the Incident Command System obtained from the United States Homeland Security Department, Federal Emergency Management Agency, Emergency Management Institute (http://training.fema.gov/EMIWeb/).

BOX 7: WHO SHOULD BE ALERTED WHEN AN INCIDENT OCCURS?

Good communication among the various stakeholders of a chemical incident alert is key to an effective and coordinated response to the event. The alert activation plan should clarify who has the authority to alert and scale up the organization, and include the prompt notification of at least:

- the local chemical incident management teams
- medical service providers and other emergency responders
- other local and national governmental agencies, e.g. emergency response organizations
- WHO if the event is of (potential) international public health concern as defined in the International Health Regulations (2005)
- neighbouring nations if necessary
- local or international nongovernmental agencies and the source of the incident if necessary.

responsible for identifying governmental departments and experts to assist in the coordination of activities associated with the management of chemical incidents (or to implement a system to do so). During a major chemical incident, local agencies may be quickly overwhelmed. To prevent this, the national authorities should be alert and responsive to any assistance requested by the local authorities.

5.5 CONDUCT A BEST OUTCOME ASSESSMENT FOR BOTH IMMEDIATE AND LONG-TERM ACTIONS

Once a chemical release has occurred, there are a number of actions that can be taken at different points in the sequence of events. An important function immediately after the incident is to identify those actions that achieve the best outcome for the health of the public and the status of the environment. These actions might include making decisions such as whether to extinguish a fire or to let it burn out; whether or not to use a chemical dispersant (and what type) in a maritime incident involving an oil spill; or whether to evacuate people from an area or to recommend sheltering in-place. Depending on the type of chemical incident, it is possible that the incident could escalate quickly and therefore there may be a need for rapid decisions and actions.

The effectiveness of a best outcome assessment will depend on the amount of information and data that arrives from the incident site and the amount of time available before a decision is required. In evaluating different possible actions, various data should be reviewed. Data regarding chemical properties may be available from the chemical information databases, site-specific information may be available from the hazardous site databases, and likely effects of the incident may have been discussed in the community risk assessments. These databases and risk assessments are described in section 3. If access to all sources of data is not available, estimates of the missing information should be made based on currently available data.

Beyond the data obtained from the various databases, information regarding the results of local environmental sampling, weather forecasts, environmental models, and predictive models can be used to predict the likely distribution (or exposure pathways) for a chemical in the area.

At an appropriate time, public health managers can compare the options for action, make a decision and assign action required to responders.

5.6 DISSEMINATE INFORMATION AND ADVICE TO PUBLIC, MEDIA AND RESPONDERS

As noted above in section 3.5, one of the most challenging tasks during a chemical release incident may be that of communicating clearly with the public, especially those individuals who are affected by the incident and those who are concerned about residual exposure. In most areas, the public is not adequately informed of the actual risks related to an incident and therefore does not understand the purpose or methods of the response actions. Therefore, it is essential to clearly and effectively communicate with the general population, including those directly affected by the event. The purpose of disseminating public information may be to advise the public to take actions (such as evacuation) or to promote effective risk-reducing behaviour.

During an incident the public will often need information about:

- the incident;
- who is in charge;
- the measures being taken to contain the release and/or stop exposure;
- who is (and who is not) currently under threat;
- what the health effects from exposure might be;
- what the public can do to protect themselves;
- how to get further information or treatment should symptoms or concerns arise, and when, where and how these services will be made available; and

- the time at which an information update will be provided.

Public warnings and directives must be accurate, clear, and repeated over more than one communication channel. Often this is done through the media, but it may also be conducted through public address systems. Although communications with the public from the national authority as opposed to the local authorities may lend some credibility to the information, the local authorities may be in a better position to convey the information more quickly and accurately. Regardless of the source, all public information emanating from the control teams must be consistent. The use of the ICS described in section 3.4 may be useful in ensuring a coordinated communication programme.

Communication skills are very important, and are best left to one or two nominated people with training in public and/or crisis communication. Using a single spokesperson (who is trained in disseminating information to the public) with excellent communication skills and a good record of trustworthiness can be a very effective way to ensure a consistent message and prevent overreaction. The spokesperson should attempt not to over-assure the public; should acknowledge uncertainty and fear; should explain where to find additional information; and should recommend specific actions that people can take. The spokesperson should always tell the truth, even if it means stating "I don't know". Several principles have been developed for use when preparing risk communication messages. Box 8 displays one such principle.[1]

It is also important to assess the concerns of the community about the possible contamination of their environment and their own exposure. These concerns may indicate a need for further study or for remediation, and may also guide the presentation of the results of

[1] Reynolds B. *Crisis and emergency risk communication.* Atlanta, GA, United States Centers for Disease Control and Prevention, 2002. US DHHS. *Communicating in a crisis: risk communication guidelines for public officials (www.riskcommunication.samhsa.gov/index.htm).* Health Canada. Crisis/emergency communications guidelines (http://www.phac-aspc.gc.ca/sars-sras/cecg-ctcu/hc-cecg.pdf). The Peter Sandman Risk Communication Website. *Crisis communication: guidelines for action* (www.petersandman.com/handouts/AIHA-DVD.htm).

BOX 8: THE STARC PRINCIPLE

Simple	People want to hear words they understand
Timely	People want information as soon as possible
Accurate	People want information that is to-the-point
Relevant	Responses to the public's questions should be factual
Credible	Openness is the key to credibility

the investigation to demonstrate that concerns have been addressed.

In addition to the information required by the media and the affected population, responders may have information needs. These may include information on requirements for PPE before entry to the scene, on decontamination and medical treatment guidelines, and on the outcome of the rapid assessment for each of the possible incident management strategies.

5.7 REGISTER ALL EXPOSED INDIVIDUALS AND COLLECT SAMPLES TO ESTIMATE EXPOSURE

It is important to establish registers of potentially affected individuals as soon as possible following a chemical release, while verification and degree of exposure may have to be determined later. Rapid registration is critical for several reasons:

- People's recollection of symptoms and whereabouts can become confused over time (partly through memory loss, and partly through publicity of the incident).
- Records of who was part of the emergency response may be incomplete, including those maintained by fire, police and ambulance departments.
- Volunteers, who often arrive to provide assistance in response to certain chemical incidents, may be more exposed than the general population and may afterwards return to distant locations without being registered.

Potentially affected individuals include emergency responders, victims exposed to the chemical (with and without physical injury), bystanders, volunteers, employees of the affected and neighbouring facilities, people in transit near the incident site at the time of the release, including passengers on public transport and visitors to events or attractions. It is difficult to make an exhaustive list that would cover all possible scenarios.

Ideally, all registers of exposed individuals should initially contain:

- details of the person (e.g. name, age, sex, address, medical history)
- the way in which the person was affected by the incident (e.g. exposure to chemical, loss of home, job or relatives)
- exposure time (time of day and duration)
- exposure pathway (i.e. air, soil, or water)
- symptoms, including their time course
- samples collected (e.g. biomarkers)
- treatment indicated and provided.

Registers of exposed individuals require a set of standardized definitions, permission from the individuals, assurance of confidentiality, an updating mechanism and a commitment to devote the time and resources needed to develop such registers. Registration is discussed further in section 6.2.

5.8 CONDUCT INVESTIGATIONS DURING THE INCIDENT

Ultimately, all decisions made during a chemical incident should be made with a view to improving or protecting the health of people at risk of being exposed to the chemical, the explosion or the fire. Therefore, these decisions should be evidence-based as far as possible, using information from human exposure, epidemiological or animal toxicological studies. Whereas information from previous incidents can be very helpful, data and information from the

CASE STUDY 13: RELEASE OF CHLORINE GAS FROM FACILITY – BATON ROUGE, UNITED STATES

During the early hours of 20 July 2003, workers at a refrigerant coolant processing facility noted chlorine gas leaking into the refrigerant coolant system. Within 15 minutes of noticing the leak, workers were forced to evacuate the property because of the chlorine gas. After 20 minutes, plant officials raised the incident level to include communities surrounding the plant. Within half an hour of raising the incident level, local authorities in the community advised residents within a half-mile radius of the plant to shelter-in-place. Local authorities activated community sirens and an auto-dialler system to notify residents of the advice. Residents outside the half-mile radius heard the community sirens, but did not receive the auto-dialler message. As a result, these residents were confused about the extent of the threat and the precautions they should take to ensure their safety.

Plant workers needed 3½ hours to shut down the chlorine supply manually because automatic shutdown systems were not in place. Overall, authorities estimated that 6 500 kilograms of chlorine gas was released during the incident. Due to the prolonged release, emergency responders and the small number of residents who were outside the advisory zone noted strong chlorine odours.

KEY POINTS

- Sheltering-in-place and evacuation plans should be part of the Chemical Incident Plan. Various resources, such as decision matrices and decision trees, are available to help to make appropriate decisions.
- Hazard analyses should review all equipment, procedures, and likely scenarios, including non-routine situations such as a prolonged release.
- Awareness campaigns to educate residents on the proper response during a chemical release should be conducted for residents near chemical facilities. This education should include instructions on the way residents (including those outside the affected area) can obtain information during an emergency.
- Consider all means of communication with the public including those not at risk.

incident at hand are invaluable in assisting in the decision-making process.

The primary objective of conducting investigations that assess effects on health or on the environment during an incident is to quickly offer advice throughout the incident, primarily on protection and treatment. A secondary objective is to organize epidemiological investigations in order to contribute to the database of public health and toxicological information. This information can also be used to implement long-term treatment or remediation plans.

To offer advice about protection, information obtained during the best outcome assessment (section 5.5) will be needed, such as the source of the incident and type of chemical, the likely exposure pathways, and information from the databases about the type, frequency and severity of the health effects caused by the incident. To offer advice about treatment, all those exposed to the chemical or suffering from acute health effects will need to be identified and followed up in epidemiological investigations. Epidemiological investigations can also be used to determine the effectiveness of the response to an incident and the treatments given to the victims. More information on these investigations is given in section 6.2.5.

There is often a conflict between the need to contain the chemical incident during the initial emergency stage, and the need for careful documentation of exposure and effects. Therefore, procedures should be agreed upon with the emergency service personnel, preferably during the pre-incident planning phase, for initiating these epidemiological investigations as rapidly as possible and detailing which agencies will contribute, preferably during the acute phase. For example, if measurable chemical levels in the body decline quickly, specimens taken days after the incident will not accurately reflect the exposure of individuals. Ideally, these procedures should be outlined in the chemical incident plan, as was the case for the explosion at the Hertfordshire oil depot described on page 66.

Exposed individuals should be monitored if possible. On-site workers are likely to offer good monitoring accessibility during an emergency. However, they may already have been exposed to the chemical(s) during their normal workday. The emergency responders are also likely to offer good monitoring accessibility, as long as the monitoring equipment does not interfere with their operations. Finally, the public's accessibility for monitoring is likely to be poor, due to the potentially large number of people affected and the difficulties of locating them. This calls for the establishment of a network of laboratories, in which a central laboratory or a number of specialized laboratories have expertise in assessing exposure to the variety of chemicals that may be involved in an incident, through the analysis of biological and environmental samples. These laboratories should have complete analytical and sampling protocols, and they should periodically participate in exercises, including exercises using samples spiked with chemicals that could potentially be involved in a chemical incident.

CASE STUDY 14: EXPLOSIONS AND FIRES IN AN OIL STORAGE DEPOT – HERTFORDSHIRE, ENGLAND

At around 06:00 on Sunday 11 December 2005, several explosions occurred at the Buncefield Oil Storage Depot, a large tank farm located in Hertfordshire, England. At least one of the initial explosions was massive and resulted in a large fire, which burned for several days, destroying most of the site and emitting an extensive plume that dispersed over southern England and beyond.

The explosions at the Buncefield Depot probably resulted from ignition of a vapour cloud created by the overfilling of one of the tanks. The loss of fuel containment is likely to have been due to a failure of the instrumentation system of the tank.[a] However, uncertainties remain about why the explosion was so violent.

The number and severity of injuries in Buncefield were exceptionally low for this type of incident. Only 43 people were injured,[b] none seriously and there were no fatalities. There was significant damage to both commercial and residential properties in the area. About 2000 people with damaged homes and workplaces were evacuated, while the other residents of the area were told to shelter in-place.

Overall, the response of the emergency services was impressive. At the peak of the fires, at lunchtime on Monday 12 December, there were 20 support vehicles, 26 Hertfordshire trucks from the fire brigade and 180 fire-fighters on site. As instructed by the chemical emergency plan, the emergency service providers led the initial response to the incident while working closely with other responders such as the Environment Agency. The latter provided advice on how to minimize the contamination of the nearby water during the fire-fighting activities. In the early phase of the incident, the Health Protection Agency stood ready to provide advice and contribute to the risk assessment. Meanwhile, both the Environment Agency and the Health Protection Agency were supported by the emergency service personnel, who assisted with obtaining information during the early hours of the incident. Once the fires were extinguished, the site was handed over to the investigation team.

The Buncefield incident highlights the necessity for a well-coordinated emergency plan when responding to a chemical event, as well as the importance of providing advice to emergency responders and to the public.

The incident also raises the question of the location of hazardous sites near commercial and residential neighbourhoods. During the land-use planning of the area, the formation of a huge cloud of fuel vapour from tank storage was not considered a sufficiently credible scenario to be taken into account. The incident shows that more attention should be paid to the total population at risk from a major hazard during the planning phase.

KEY POINTS

- A good preparedness plan should include communication channels between the various stakeholders in the initial response to the incident as well as in its aftermath.
- The plan should define the role of the stakeholders during an emergency.
- Hazardous sites should not be located in the vicinity of commercial and residential areas.

[a] Buncefield Major Incident Investigation Board. *Initial report to the Health and Safety Commission and the Environment Agency of the investigation into the explosions and fires at the Buncefield oil storage and transfer depot, Hemel Hempstead,* on 11 December 2005. Published on 13 July 2006.
[b] The Buncefield Investigation. *Progress report.* 21 February 2006.

6 RECOVERY

A chemical incident may continue to affect the community and individuals involved years after the release and after acute medical treatment has been completed. Full recovery from a severe incident may not be feasible theoretically or in practice. As such, recovery in this publication refers to a broad spectrum of activities including follow-up, aftercare, restoration and rehabilitation. Recovery is not exactly defined from an operational perspective. For practical purposes, the recovery phase is assumed to start after the incident management command and control structures (ICS) of the initial incident have been scaled down.

Since disasters engender different types of stressors such as threat to one's life, confrontation with the injured and deaths, bereavement (family member and friends lost), significant loss of property (e.g. houses), and social and community disruption that have lasting effects, the impact of disasters is usually much broader than the acute health problems that occur.

Chemical incidents, much like individual traumatic life events, cause well-documented physical and psychological complaints, as well as medically unexplained physical symptoms (MUPS).[1] The physical damage and associated health end-points and complaints can take many forms, the nature of which is closely related to the nature of the exposure. The most common long-term reactions to such incidents are anxiety disorders, depression, "persistent recollection", substance abuse and MUPS.There is no clear link between the nature of psychological or medically unexplained physical symptoms and the nature or cause of the incident. While the problems experienced by victims used to be regarded as a fact of life, they are now increasingly being interpreted in their medical and psychological context.

Recovery from the physical injury may take years. Blast, fire and some acute chemical exposures may lead to permanent damage (Case Study 17: Bhopal, India – 20 years later, page 82). In addition, chemical incidents may lead to long-term contamination of land and water, and thereby cause long-term exposure via a number of contact media and routes.

The etiology of psychological and medically unexplained symptoms is determined by multiple factors. Determinant factors are classified as predisposing (variability in personal susceptibility to emotional imbalance), precipitating (external circumstances which prompt the emergence of health complaints in susceptible persons) or perpetuating (those which cause the complaint to persist, and stand in the way of recovery). Most victims regain their emotional balance without professional assistance within 18 months, but some experience health complaints of a more long-term nature.

[1] Health Council of the Netherlands. *The medium and long-term health impact of disasters.* The Hague, Gezondheidsraad, 2007. Report 2006/18E (http://www.gr.nl/pdf.php?ID=1487&p=1).

Well-organized adequate incident management is also important from the perspective of preventive health care, since it limits the number of casualties and helps to provide safety for the survivors. The emphasis of psychosocial services immediately after a disaster should be on the promotion of natural recovery and self-sufficiency. Prompt and adequate information is a key element in helping victims to regain control. Effective treatment exists for the most important long-term psychological sequelae such as depression, anxiety and post-traumatic stress disorder. Provision of such treatment should be part of the recovery activities.

There are several important tasks that must be done following a chemical release incident or near incident. These tasks are designed to assess public and environmental impacts in order to design appropriate care, remediation and protective actions. It is also important to evaluate the events that led to the chemical release, as well as to assess the public health response in order to prevent recurrence of the incident and to improve the overall response.

Public health can play an important role in four of the many activities that need to be undertaken in the recovery phase:

1. organization of health care to treat victims and support them in regaining control of their lives, including a central access to information and assistance;
2. risk and health outcome assessment, including exposure, environmental and human health assessments;
3. implementing remediation and restoration actions;
4. evaluation, including root cause analysis, response and lessons learned.

6.1 VICTIM SUPPORT

By definition, an incident is marked by chaos and disruption. The restoration of order and safety, and the preclusion of any further uncertainty, will do much to restrict adverse psychological and medically unexplained effects in the medium and long term. The main risk factor in this regard is the degree to which the events impact and intrude upon people's day-to-day lives. The greater the number of fatalities, the greater the number of survivors who will develop psychopathological symptoms. Rapid availability of appropriate assistance and adequate information must therefore be regarded as an important preventive measure against post-disaster health complaints. Accordingly, it is essential that action to bring survivors to safety, to treat casualties, provide psychosocial "first aid" such as housing, food and clothing, must be undertaken as quickly as possible and be organized well.

The installation of a single point of contact which the public can approach with all problems and questions concerning a recent incident (Information and Advice Centre, IAC)[1] may greatly contribute to the mitigation of long-term health consequences of incidents. Victims, families and friends will feel a strong need for information about the events, what to expect next and what they can do themselves. An IAC can assume immediate responsibility for victim support without assuming any of the existing tasks and responsibilities of other agencies. The IAC must know the current status of the victims, so it can activate appropriate support services, and inform and advise the relevant agencies. It must also maintain contact with all persons affected by the incident. In addition to this general information and advice function, the IAC can play a role on behalf of individual victims and their relations, in mediating between people with questions, problems and health complaints on the one hand, and the various support, counselling and medical services on the other. The essential feature is that people must be able to contact the IAC with any and all problems, rather than having to decide for themselves which organization would be able to provide assistance. The IAC acts as a "referral service" which knows (or can find out) which organization can address which problem.

[1] Health Council of the Netherlands. *The medium and long-term health impact of disasters.* The Hague, Gezondheidsraad, 2007. Report 2006/18E (http://www.gr.nl/pdf.php?ID=1487&p=1).

Immediately after a disaster, the IAC will mainly be concerned with providing information and advice on pressing practical matters such as shelter, food and clothing. Once the immediate issues have been resolved, attention will be turned to the resumption of normal day-to-day life and to matters of medical and psychosocial care, compensation claims, transitional arrangements and relocation.

6.2 RISK AND HEALTH OUTCOME ASSESSMENTS

Adequate victim support requires accurate and timely information about the victims that may require specific risk, needs and health outcome assessment studies to produce the data. Such studies are particularly valuable when (management) information is needed for the (public) health management of incidents. In general terms, the objectives for follow-up studies of the affected population are:

1. Production of information required to optimize individual health care:
   - management information to identify the need for additional health care resources, or changed health care needs.
2. Production of information to optimize public health provision:
   - number, nature and course of health outcomes and victims' needs;
   - identification of groups at particular risk;
   - current and future health care needs of any type (including psychosocial support);
   - other needs of the affected population, such as for information or housing;
   - prognosis for possible health outcomes.
3. Contribution to scientific knowledge of the health outcome of chemical incidents:
   - etiological studies of health outcomes, understanding of disease mechanisms;
   - evaluation of effectiveness of emergency response, preventive measures and medical treatment.
4. Contribution to societal interventions to signal recognition of the problems encountered by the victims and to build or strengthen a reputation as a proactive, caring government.

It is crucial to recognize that the initiation of a study creates expectations in the affected community. Since the objective of any study determines its design and the possible application of the outcomes, it is advisable to communicate very clearly about the objective and duration of the study, and what conclusions can and cannot be inferred from the study. For instance, a study aimed at identification of susceptible groups may not produce health data relevant at the individual level. If the victims are interested in or expect such information, the study will not meet their objectives. If performed well, such assessments not only enable the public health authorities to offer advice regarding protection and treatment, but can also satisfy the information needs of the victims and contribute to the database of public health and toxicological information, both nationally and internationally.

To offer advice regarding long-term protection and treatment, information will be needed about the incident, including the source and type of chemical, and the likely exposure pathways. As discussed in section 5, collection of this information should begin during the incident. Public health and environmental professionals will also need information from the databases about the type, frequency and severity of the health effects of the chemical – ideally at different exposure levels. Exposure to the environmental pollutants will need to be assessed and considered in the context of risk for health effects and disease in the population, in order to provide follow-up for as long as necessary. In some cases, including when the existing knowledge of the toxic properties of the released chemical is insufficient to support a risk assessment, it may be necessary to study the health outcomes in the exposed population directly.

Collection of these data will help to:

- identify the populations or individuals requiring further follow-up and treatment;
- provide estimates for planning and resource allocation;

- determine when (or if) the risk of exposure in certain areas falls below a protective action threshold;
- uncover continuing problems;
- assess the success of mitigation efforts;
- support environmental and community remediation efforts;
- provide information for litigation and compensation;
- add to the understanding of the effects of the incident;
- supply baseline data for long-term follow-up studies;
- develop background reference material for use in future similar incidents; and
- add to toxicological databases.

6.2.1 Registration

Following an incident, it will be necessary to obtain information from the affected population regarding their involvement in the incident including exposures and any health effects that may have resulted from the exposures. This information may be useful, for example, for identifying individuals who were unknowingly exposed, or may help to determine the most effective treatments. The first step in this process is to accurately register all individuals affected by the incident.

People can be affected by a chemical incident in many ways: by exposure to chemicals, loss of their home, job and/or relatives and physical injury among others. All these factors together determine the likely health outcomes for the victims and their nature and severity. Victims are defined as "exposed" to a chemical when they have inhaled, ingested or come into dermal contact with the chemical. The objective of the register is to identify all those exposed, potentially exposed or otherwise affected individuals, as they are at risk of potential acute or chronic health effects (see also section 5.7).

6.2.2 Population exposure assessment

The first step in a human health assessment is the development of **an exposure index**, by determining **who has been exposed** and **the degree of exposure** to the pollutant. This step generally involves one or more of the following: questionnaires, biological measurements and environmental measurements. The highest degree of certainty of exposure is the actual measurement of the chemical or its metabolites in the potentially exposed population. However, depending on the toxicokinetics (i.e. absorption, metabolism, distribution and excretion) of the chemical, the time elapsed since exposure, and the availability of biological samples, this approach may not be possible. The next level of certainty involves measuring the chemical in an appropriate environmental sample. In ideal circumstances, this is done by measuring the levels of pollutants over time (in the environment, and both at the route of entry into and within the bodies of all the exposed individuals). These measurements will assist in designing a remediation programme. Both of these approaches require a carefully developed questionnaire.

Collection of samples – biomarkers (BM) of chemicals and their effects

The nature of an unknown chemical contamination may in some cases be deduced from the health effects noted. Clinical signs and symptoms can, in some cases, point with a high degree of certainty to exposure to a specific chemical or chemical class. The most common signs and symptoms of chemical exposure are nausea, vomiting, headache, irritation of the skin or eyes, malaise, respiratory problems and central nervous system symptoms. These are nonspecific signs and symptoms that may reflect exposure to many different chemicals, or may be related to other illnesses not associated with chemical exposures. In some instances, specific diseases are associated with specific acute chemical exposures but may take several weeks to months to develop. Such an instance is described in the Seveso case-study (section 6, page 75), where acute exposure to dioxin led to chloracne several months later. Certain organophosphates might also induce polyneuropathy weeks after exposure.[1] The nature of contamination with an unknown chemical might in

[1] Lotti M, Moretto A. Organophosphate-induced delayed polyneuropathy. *Toxicological Reviews*, 2005, 24:37–49.

other cases be determined or confirmed by biological measurements. However, this is only possible if sampled correctly at the appropriate time and processed by a specialist toxicological laboratory.

As shown by the endosulfan mass-poisoning in India (section 4), page 51, biological measurements, both of exposure and of the effects of exposure, can be an important tool for assessing chemical exposures. Unfortunately, there are no blood or urine tests that can positively confirm an individual's exposure to many of the thousands of chemicals in regular use throughout the world. Indeed, there are comparatively few sensitive and specific biomarkers for the array of hazardous chemicals used in commerce or that occur naturally. Also, testing for biomarkers of exposure and biomarkers of effect requires proper equipment and the use of specific sampling and handling techniques depending on the chemical or class of chemicals being tested for, and many of the analyses can only be conducted in specialized toxicology laboratories, which should be contacted prior to sampling. Trained personnel, availability of reagents and quality assurance are key to reliable laboratory testing. Ideally, the public health officials would invest in the development of qualified laboratories in order to ensure an effective performance when necessary.

Biomarkers of exposure (exposure BMs)

Biomarkers of exposure (exposure BMs) are measurable levels of the parent chemical or its metabolites found in one or more body fluids or tissues in samples from an exposed population. Sensitive, replicable assays of human body burden for some contaminants are available, but often must be performed within a specified, often very short, time period following exposure. For the most common chemicals involved in chemical incidents (e.g. chlorine, phosgene, asbestos, and particulates) there are comparatively few biomarkers. Moreover, using exposure BMs may not provide a definitive conclusion that there is a link between exposure and a chemical incident, especially for chemicals that may be present at low concentrations in the natural environment. Therefore, it may be important to gather also information related to hobbies, secondary occupations, source of water supplies, and on any other potential sources of exposure.

Some degree of exposure to a variety of contaminants is common in most countries. Some countries conduct population-based sampling to measure background biological levels of some contaminants. Databases such as that maintained by the US Centers for Disease Control and Prevention's National Center for Health Statistics, based on its National Health and Nutrition Examination Surveys (NHANES),[1] offer one source of reference levels for studies. The NHANES database currently includes biomarker data for 148 chemicals, including heavy metals such as lead and cadmium, polycyclic aromatic hydrocarbons, polychlorinated biphenyls (PCBs), dioxins, and many pesticides.

A preliminary exposure survey should test samples from the subgroups most likely to be highly exposed, or those most vulnerable to exposure. If samples from this group do not show measurable levels, further investigation of other groups is unlikely to be beneficial and there may be no need for a more comprehensive environmental monitoring programme.

Biomarkers of effect (effect BMs)

For many contaminants or situations, it is not possible to study biomarkers of exposure. In some cases, this is because the half-life of the chemical within the human body is short and too much time has passed since exposure. In some cases, exposure BMs cannot be utilized because appropriate laboratory tests are not available. In other cases, the chemical may not enter the body but has a local effect only (such as skin rashes or respiratory irritation).

In these circumstances, it may be possible to measure intermediate health effects of exposure by using physiological measurements known to change with exposure such as enzyme inhibition. Many of these measurements (biomarkers of effect) are frequently

[1] National Health and Nutrition Examination Survey home page (http://www.cdc.gov/nchs/nhanes.htm).

tested in routine health care to diagnose a wide variety of conditions, most of which are not associated with environmental contaminants. The changes they measure, such as changes in red blood cell count associated with lead poisoning, are also associated with other conditions, and care must be taken to evaluate all possible causes. Using more than one measurement indicative of exposure to the contaminant can be helpful in these cases. A reference group chosen using an appropriate sampling strategy can also help researchers to assess whether abnormalities observed in a measurement are associated with the exposure of concern.

Various publications have included detailed batteries of tests of immune function, neurobehavioural, and respiratory parameters which have been widely used and validated in environmental investigations. It may be necessary to carry out pilot studies to ascertain which effect BMs, and at what levels, are associated with known doses of agents to which a population has been exposed, in order to validate the biomarkers used in studies or in clinical situations examining the current incident. Here also, the study may need to be conducted rapidly, if the biomarker of effect is readily reversible.

Other relevant information

Whether or not biomarkers are measurable, evaluation of the affected population should consider the following:

- occupation and specific workplace;
- special features of workplace exposure such as working in a confined space, level of ventilation (e.g. whether doors are open);
- whether indoors or outdoors at the time of exposure;
- level of physical activity;
- immediate symptoms such as burning or itching which may signify high exposure;
- rate of exposure-related symptoms in those exposed, which may reflect dose;
- time from exposure to onset of symptoms – short duration may indicate a high dose or a very toxic substance, such as cyanide. For chemical incidents, the latency is typically short (seconds to minutes), so this is the usual scenario. However, some chemicals such as phosgene have both immediate and delayed effects, while other chemicals, such as dioxin, have a latency ranging from hours to days;
- special features which may affect absorption within the body (e.g. smoking, exercise, skin abrasions, pica);
- measures taken to reduce contamination of the individual (e.g. washing skin and removing clothing immediately);
- scorching of vegetation;
- animal sentinels, which may be affected by the incident;
- traumatic experiences such as loss of relatives, housing, or job.

6.2.3 Environmental assessment

Environmental modelling or rapid environmental sampling may enable a determination of the media that have been contaminated, the level of contamination in the media, and the geographical distribution of contamination. Modelling can also be used to identify the populations likely to have been exposed.

Environmental monitoring programmes should focus on evaluating the concentrations of chemical(s) released (as well as their potential decomposition products) in all the environmental media that individuals could be exposed to. Specifically, potential contamination of air, water and soil should be considered in areas surrounding the release site.

Collection of samples: environmental media

As discussed in section 4.2, environmental measurements are critically important, but require well-equipped and skilled personnel to carry them out. It is therefore essential that a systematic plan is developed for the areas and media (including food and drinking-water) to be sampled, as well as the required time frame for sampling. The sampling plan should include the time, frequency, sampling methodology, and comparisons to be made, to obtain an accurate representation of

WEB LINKS 8: ASSESSMENTS

For more information on conducting environmental health assessments visit Australia's Department of Health and Ageing at: http://enhealth.nphp.gov.au/council/pubs/pdf/envhazards.pdf

conditions. The sampling team should be supported by laboratory facilities that carry out appropriate tests, and that have stringent quality assurance and quality control procedures. Ideally, laboratory facilities should be certified for the specific analyses that they will be conducting.

There is only one opportunity to obtain air samples for determination of exposure levels during the emergency itself. While it may not be feasible to collect water or soil samples during the emergency, air sampling in the field is usually possible, even if at locations somewhat distant from the event. If sampling in the plume is attempted, chemical emergency managers may need to coordinate (and train) well-protected fire personnel or environmental officers to conduct the sampling; these people need special advance training to accomplish this task effectively and without endangering themselves. When water or soil has been contaminated, sampling can usually be done in the days following the incident. However, if the chemical incident was such that the site had to be neutralized immediately, for example, by thoroughly rinsing or hosing, samples may not be available. In such cases, biomonitoring, as discussed above, may be a good option for estimating exposure.

Monitoring at the source of contamination should continue well beyond the point at which the release has been controlled, to confirm that the release has indeed been controlled. The media likely to be contaminated should be monitored, and personal monitoring should be conducted, to determine the concentrations to which populations or individuals are actually being exposed as they go about normal activities. For a practical example, see the Songhua river case-study (section 3), page 41.

If environmental modelling has been conducted to assess the distribution of the chemical of concern, it may be helpful to validate model predictions by sampling outside the predicted zone of contamination. This may be particularly useful if there are reports of health effects in these areas. Many models are general models which may be too simplistic for handling complex situations such as dispersion around hills or buildings. Therefore, more complex models that require more data inputs may be necessary for more reliable predictions.

If the source and nature of contamination remain uncertain, but adverse health effects continue, environmental epidemiological detective work may be able to identify likely types or sources of chemicals. Information regarding characteristics of the affected population, such as geographical residence, water supply, occupation or leisure pursuits, or use of a particular food or product, can be used to generate hypotheses, which can be tested by environmental or biological measurements.

Long-term environmental monitoring

In many cases, once an incident is over, the environment may continue to be contaminated and this contamination may continue to affect people via many contact media and exposure routes. Often, the level of contamination may need to be monitored regularly and over a long period, and the possible effects on people's health assessed regularly. Assessing environmental contamination is an important component of effectively following up after a chemical release incident (or near incident). Data from long-term environmental monitoring following a chemical release can be used to:

- Evaluate variations from *baseline* environmental conditions.
- Characterize severity and extent of the chemical incident, and therefore, potential pathways for human exposure.
- Design remediation programmes, and also evaluate effectiveness of remediation actions.

- Evaluate potential impacts on human health following incidents using risk assessment techniques. This can be an important alternative to conducting epidemiological studies.

6.2.4 Health outcome assessment during or immediately after the incident

Acute health effects should be assessed immediately after a chemical incident. This involves obtaining data on the potential health effects of the chemicals of concern, as well as psychosocial-related effects such as insomnia, anxiety, and stress. Data should be collected on the functional, physical, morbidity and mortality outcomes that are related to either the exposure to the chemical, or to the stress associated with the chemical incident. All this information can then be used to provide follow-up advice on protection, individual treatment and population interventions.

6.2.5 Intermediate and long-term effects of the incident

Once the short-term assessments have been conducted, and if necessary and appropriate, an epidemiological study may be initiated to follow the exposed population. The primary goal of such a study is to identify potential chronic conditions related to the incident and offer treatment if necessary. Additional objectives of an epidemiological study are to:

- provide information regarding the probability of health effects;
- determine whether the particular chemical has the potential to cause chronic health effects following an acute exposure;
- delineate the exposure-dose/health-effect relationship; and
- contribute to the database of public health and toxicological information.

For a practical example of a long-term health assessment, see the Seveso case-study (section 6).

Purpose of long-term epidemiological health outcome assessments

The possible objectives of health outcome studies have been discussed in section 6.2. Relatively little is known about the toxic effects of chemicals in non-occupational settings, because historically resources have been focused on occupational environments. In addition, it can be difficult to study the effects of low, chronic exposures to multiple chemicals and assessing the health effects associated with these low-level exposures is very complex.

Ideally, the toxic effects should be correlated with an exposure metric, which requires data on the levels, routes and duration of exposure and the severity of the health effects. If the exposure-response is known, it should be possible to inform the public of the potential outcome of the incident as well as to recommend protective measures. The psychological and medically unexplained symptoms are less well correlated with the chemical exposure, and can be better predicted with a different set of determinants, including: loss of relatives, livelihood and home; personality and functioning before the incident; being witness to gruesome events; and social support.[1,2]

It is obviously not possible to collect data on large populations, within the framework of controlled experimental studies, for logistical and ethical reasons. Chemical incidents, where the population is put at risk, therefore represent unfortunate, but genuine research opportunities. Large-scale analytical epidemiological studies are expensive in terms of time and resources, and require participation by public health and environmental professionals as well as the public.

It is important to understand the benefits of these large-scale studies, including in designing and implementing appropriate remediation and restoration programmes, as well as in preventing the recurrence of chemical incidents. Another benefit of conducting large-scale epidemiological studies is to provide information on health effects to exposed populations. Communities

[1] Health Council of the Netherlands. *The medium and long-term health impact of disasters.* The Hague, Gezondheidsraad, 2007. Report 2006/18E (http://www.gr.nl/pdf.php?ID=1487&p=1). Havenaar JM, Cwickel JG, Bromet EJ, eds. *Toxic Turmoil. Psychological and societal consequences of ecological disasters.* New York, Kluwer Academic Publishers, 2002.

[2] IJzermans CJ, Dirkzwager AJE, Breuning E. *Long-term health consequences of disaster. A bibliography.* Utrecht, NIVEL, 2005 (http://www.nivel.nl/pdf/Long-term-health-consequences-of-disaster-2005.pdf).

CASE STUDY 15: AIRBORNE RELEASE OF DIOXIN FROM AN INDUSTRIAL PLANT – SEVESO, ITALY

Shortly after noon on 10 July 1976, a valve broke at the Industrie Chimiche Meda Societa Azionaria (ICMESA) chemical plant near Seveso, Italy, resulting in the release of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), commonly known as dioxin. The chemical cloud rose approximately 50 m into the air covering a largely residential area of about 18 km^2. While the exact amount of dioxin released is not known, experts estimate that between 100 g and 20 kg of dioxin was released.

Within hours, several children experienced skin inflammation. In the months that followed, other people developed chloracne, a skin disorder now known to be a symptom of dioxin poisoning. Within a few days, 3300 animals, mostly poultry and rabbits, died due to the chemical exposure, and an additional 80 000 animals were slaughtered to prevent dioxin from moving through the food web. Fortunately, there were no human fatalities as a direct result of the accident.

At the time, Italy had few procedures in place for responding to industrial accidents, and the lack of direction on the part of officials led to fear and uncertainty for residents of the area. The communities surrounding the chemical plant were not advised of the release for approximately one week, and evacuation of individuals in high-risk areas did not commence until two to three weeks had passed. Because dioxin is persistent in the environment, scientific studies of the long-term effects of dioxin for exposed individuals and their children are still ongoing.

As a direct result of this incident, the European Commission passed industrial safety regulations entitled the Seveso Directive in 1982. These regulations have been updated several times and the current version is the Seveso II Directive. The Directive requires facilities to establish emergency response plans that include the objectives of communicating with the affected public and implementing measures to protect the public and the environment in a timely manner following a chemical incident.

KEY POINTS

- The capacity should exist to evaluate and analyse the delayed and long-term health effects of persistent pollutants associated with chronic disease such as cancer.
- Preparedness plans should include information on how and when information will be released to the public.
- Preparedness plans should include methods to protect the public and the environment following chemical releases.

sometimes request that studies be conducted because risk communication efforts have not been effective in allaying all concerns. Exposed individuals often also desire to know that "someone is doing something" in a community where response efforts are perceived to be incomplete. However, epidemiological studies should not be carried out with the sole purpose of appeasing the public, but should only be conducted if there are sound scientific reasons for doing so.

Studies requiring fewer resources than analytical epidemiological studies can be used to assess the feasibility of a major study, to address the concerns of the public, and to generate hypotheses for further studies. These include descriptive studies, which are described below.

Types of health outcome assessments[1]

Methods to evaluate the effects on health in the general public following a chemical release incident can be generally categorized into two groups: **descriptive studies** and **analytical studies**. The distinction between these two methods is not absolute and a descriptive study can form the basis for an analytical study.

A descriptive study is one that shows a change in either exposure or health effect. It may also be able to show that exposure and health effects are associated. In some cases, descriptive studies may be able to show that there is a time sequence and that the exposure precedes the effect.

[1] Information from World Health Organization. *Assessing the health consequences of major chemical incidents: epidemiological approaches.* Copenhagen, World Health Organization, 1997.

Analytical studies are intended to go further and determine, in all cases, whether the exposure came before the effect and that there is a statistical probability that the exposure caused the effect. Analytical studies are typically larger and more expensive than descriptive studies.

The decision on which study method to use to assess public health following a chemical incident will depend on several factors, including the number of people at risk, the social and political need to find answers, and the resources available. It is crucial to choose the appropriate study design, including method, purpose, and hypothesis, before any work is started. Also, it is important to communicate the purpose and structure of any study to all major parties concerned with the incident.

Descriptive studies

Disease and symptom prevalence studies. It is very tempting to quickly collect data on individuals with symptoms and signs of chemical exposure. However, unless a control or reference group is included, there will be uncertainties regarding the relationship of the health effects to the exposure. Results from poorly designed disease and symptom prevalence studies can be difficult to explain to the public.

Cross-sectional studies attempt to compare diseased and non–diseased populations with regard to current exposure, or exposed and non-exposed populations with regard to current health status, at a point in time or over a short period. Cross-sectional studies resemble disease and symptom prevalence studies but they are more formally structured, with precise definitions for disease and health outcomes of interest and with well-defined measurements or surrogate factors representing exposure levels.

Ecological studies are those in which the unit of observation is the population or community. Rates of illness and exposure are examined in each of a series of populations and their relationship is studied. The question being investigated is usually whether a population has been exposed to a sufficient amount of the contaminant to increase the rate of health effects above that of similar populations in non-exposed areas.

Cluster investigations resemble ecological studies in that presence in an area during a specific time period is often used as a surrogate for suspected exposure. However, cluster analysis uses special statistical techniques to deal with small areas and small populations, and health effects information may involve active case-finding and more precise case-definitions.

Cluster investigations are often conducted in response to a community's anxiety that a perceived increase in disease frequency is linked to an environmental hazard. A cluster may also become apparent if individuals with a new or unusual illness have been listed during the routine population health surveillance programme (section 4.2).

There are two important ways of comparing data from descriptive studies: using geographical (spatial) comparisons or time (temporal) trends. Table 3 summarizes the input data, study design, analysis and results from several descriptive studies that may be used to evaluate public health risk following a chemical release incident.

Analytical studies

An analytical study attempts to show an association between exposure and subsequent illness, or to identify a possible causative agent in a group of people with a particular illness. These types of studies compare the incidence or frequency of health effects in relation to exposure. It should be noted that in any large chemical incident, it is usually not possible to study all of the exposed individuals. One should instead aim to study an exposed population which includes individuals, such as children, the elderly, or those with pre-existing illnesses, who may be particularly sensitive to the effects of the chemical. In any case, both exposed and non-exposed populations should consist of a randomly

TABLE 3: EXAMPLES OF DESCRIPTIVE STUDIES THAT CAN BE USED TO EVALUATE PUBLIC HEALTH RISKS AND OUTCOMES FOLLOWING A CHEMICAL RELEASE INCIDENT

Study design	Health data	Exposure data	Analysis	Results
Survey/cross-sectional	Symptoms and signs in the population	Individual, qualitative	Comparison of different exposure groups	Frequency of symptoms (including annoyance/anxiety) in different groups
Cross-sectional (random samples or cluster samples)	Biological measurements	Individual qualitative and/or quantitative	Comparison of different exposure groups	Correlation between markers of health effects and exposure
Temporal aggregation	Disease occurrence	Population-wide	Time-series	Changes in rates
Spatial aggregation			Spatial comparisons	Difference between areas exposed and non-exposed
Temporal aggregation	Mortality, birth rates, etc.	Population-wide	Time-series	Short-term changes in mortality, birth rates, etc.
Spatial aggregation			Spatial comparisons	Difference between exposure groups

selected (stratified) sample, and should be evaluated periodically following exposure, for example at 0, 3 and 6 months and 1 and 2 years after the incident.

Analytical studies provide statistical evidence of causation by estimating the strength of an association between exposure and disease. Two statistical metrics often used in analytical studies include an odds ratios (OR) and the relative risk (RR). Additional evidence of causation is provided if a dose–response relationship can be identified. A dose–response relationship is crucial for risk assessment. The three usual classifications of analytical studies related to environmental epidemiology are panel, cohort and case–control studies, as discussed below.

Panel studies are used for the short-term follow-up of a group of people in whom the health effects are correlated with concurrent exposure measurements. In this type of study, each person is their own control, although a reference panel should also be evaluated to adjust for the possible confounding effects of time-dependent factors not related to the exposure, such as weather or media reports of the chemical incident.

Panel studies are relatively simple to carry out, and can be completed in a matter of days to weeks rather than months to years. These studies can form the basis for, or be used to assess the utility and feasibility of, more formal studies.

Cohort studies compare symptoms or health effects between exposed and non-exposed individuals. Results from cohort studies can be used to evaluate the association between health effects and exposure. Prospective cohort studies evaluate incidence of symptoms or health effects in exposed versus non-exposed individuals. Retrospective cohort studies evaluate frequency of symptoms or health effects in exposed versus non-exposed individuals.

Case–control studies compare the exposure history of a group of people with specific symptoms (the cases), with that of people without symptoms (the controls). This type of study may be prospective or retrospective. Case–control studies can be useful for assessing the association of specific health outcomes with certain exposures, for verifying the effectiveness of protective and treatment measures, and for identifying factors that affect susceptibility to exposure-related health effects.

Table 4 summarizes the input data, study design, analysis and results from several analytical studies that may be used to evaluate public health risk following a chemical release incident.

Limitations of epidemiological studies

Unfortunately, verifying or refuting the effects of a chemical incident using the study methods described in this section can be complex or problematic for a number of reasons, including the following:

TABLE 4: EXAMPLE OF ANALYTICAL STUDIES THAT CAN BE USED TO EVALUATE PUBLIC HEALTH RISK FOLLOWING A CHEMICAL RELEASE INCIDENT

Study design	Health data	Exposure data	Analysis	Results
Panel	Biological markers, symptoms, signs, disease occurrence	Individual	Correlation between exposure, exposure indicators and changes in health indicators	Short-term health effect
Cohort	Mortality, disease incidence, reproductive outcomes	Group exposure or individual	Comparison between different exposure groups	Incidence of long-term effect, relative risk in various exposure groups
Case – control	Rare disease outcomes (such as cancer, malformations)	Individual	Comparison of exposure history between cases and referents	Confirmation of association between specific outcomes and exposure

- The latency period from exposure to effect is often unknown, and may be long.
- Individuals move out of the area, making it difficult to track exposed populations.
- The causes of many illnesses, such as cancer, are multi-factorial, such that attributing a specific health effect to exposure to a specific chemical often requires a large number of study participants; rarely is the number of people exposed during a chemical incident large enough to provide sufficient statistical power to detect moderate increases in risk.

6.3 IMPLEMENTING REHABILITATION ACTIONS

Rehabilitation following an environmental incident can entail a mixture of remediation and restoration of the environment, actions to prevent a further occurrence, and work to improve the community's health.

6.3.1 Remediation

For the purpose of this document, remediation is the process of making the environment safer and cleaner – as defined by national regulations – after it has been contaminated by one or more hazardous chemical(s). In a broader sense, this includes contact media such as food, drinking-water, and irrigation water. Remediation may occur naturally, as with evaporation of a volatile gas, or where the chemicals involved dissipate or break down quickly. It is important to note, however, that the natural degradation of some hazardous chemicals may, in fact, produce degradation products that are more toxic than the parent chemical.

When active remediation is needed, it can involve the physical collection of the contaminated medium and its safe removal or it may require other measures to reduce the toxicity of the chemical.

The remediation process can only be fully effective when the extent of contamination has been characterized. A range of expertise is needed to assess the extent of environmental contamination, to devise appropriate decontamination measures where needed, and to ensure that it is safe for evacuated populations to return, or for public health protection recommendations to be rescinded. The extent to which contamination has reached agricultural soil, or land used by humans, and the level of contamination of crops and livestock, with subsequent risks to the food chain, must also be appraised and addressed as part of the remediation process.

Cleaning up contaminated sites or land may entail using soil stabilization or disposal technologies or biological methods of decontamination. Material such as topsoil, beach sand, equipment or crops may need to be removed for cleaning or disposal, without endangering the area where decontamination is taking place. Remediation of large bodies of water may be costly and time-consuming, especially when the chemical has become bound to the sediment. Individual decontamination of affected wildlife may also be necessary. Significant contamination of the food chain is likely to require appropriate destruction of crops, products, and livestock. Air decontamination may occur naturally within hours (or may take up to a few weeks), but occasionally ash or toxic levels of pollutants persist for months or years because of interaction with local conditions. Decontamination of the water supply systems may not be possible and they may have to be flushed out, creating a potential for further contamination of soil, groundwater, or seawater.

Sometimes, removal of the chemical may not be possible, due to technical difficulties, hazardous conditions, or because removal would cause further pollution or be too expensive. Remedial actions that reduce the volume, toxicity, or mobility of hazardous substances should be implemented as an alternative. If full remediation cannot be accomplished, it may be necessary to declare the area as "no-go", "no-use", "limited entry" or "limited use". These declarations may have to be in force for many years and can seriously disrupt the life of the community. All remedial measures may leave the environment significantly changed.

6.3.2 Restoration

Restoration is the process of returning the environment to its original state, as it existed before the chemical incident occurred. For some chemical incidents, remediation may not substantially alter the environment relative to its original state. For other incidents, extensive remediation work may cause substantial alterations to the environment.

Restoring the environment to its original state may involve landscaping and rebuilding, replacing equipment and buildings, replanting crops, and replacing animals and wildlife. As with remediation, restoration may be very expensive. Finding the resources for restoration activities may be problematic, as restoration often cannot be completed until a considerable period of time has elapsed since the incident; as time goes on, responsibilities might be more difficult to assert, leading to a decreased likelihood of financial compensation. Also, restoration may not be seen as urgent or necessary, and it may be difficult to find an organization that is both willing and able to pay the restoration costs. In most areas the "polluter pays" principle is rarely achieved.

6.3.3 Rehabilitation of public health and livelihood

As mentioned above, rehabilitation of exposed populations goes beyond remediation and restoration to include actions to prevent a further occurrence, and work to improve the community's health. Therefore, activities involved in the rehabilitation of exposed populations should address:

- Health, including monitoring for delayed disease, health services including (temporary) special services tailored to victims' needs including treatment of incident-related injury.
- Housing, including planning and reconstruction of destroyed neighbourhoods and repair of damaged dwellings.
- Quality of life, including rebuilding of recreational facilities such as parks, cinemas, theatres and sports facilities.
- Services, including shopping facilities, water, sanitation and telecommunication infrastructure and services, and public transportation.
- Economic livelihood, including rebuilding of destroyed or damaged offices or workplace facilities, and transportation infrastructure.
- Feeling of security, mainly by communication on the incident's root cause, legal prosecution of the company or person suspected of causing the incident, and measures to prevent recurrence of the incident.

Responding quickly and effectively to the concerns of a population potentially exposed in a chemical release incident is vital for the rehabilitation of a community. Great psychological stress can be caused by incidents which pose no physical hazard and require few or no protective actions. Often stress can be resolved by good communication of the measures taken to minimize exposure of the community. Also, undertaking additional investigations to make sure that neither health effects nor environmental contamination can be detected may be an effective way to reassure exposed individuals. Involving the community in plans to reduce the risk of further incidents, and to quickly alert responders and the public if further incidents occur, can be reassuring, and can be protective of the public's overall sense of well-being.

Acute and delayed health effects of acute exposure should be assessed and treated. The effects of chronic exposure on health may be alleviated by removing the population at risk from a source of continuing contamination, by eliminating the exposure pathway, or by implementing remedial action. Where hazardous concentrations of chemicals remain in the human body, measures such as chelation therapy, which is only possible for a few toxic metals, or treatment to aid the body in metabolizing or expelling the chemicals, should be provided. When levels of exposure are uncertain and the potential long-term health effects of exposure are a source of concern, long-term monitoring should be considered as a part of community rehabilitation. (See also the Senegal case study below.)

As described in section 6.2.1, registers of contaminated and exposed individuals can be established, but

CASE STUDY 16: OUTBREAK OF LEAD INTOXICATION – SENEGAL[a]

Following an unexplained cluster of deaths between November 2007 and February 2008 in children from the NGagne Diaw neighbourhood of Thiaroye sur Mer, Dakar, Senegal, investigations by health and environmental authorities revealed that the area was contaminated with lead from the informal recycling of lead batteries. In addition, siblings and mothers of the deceased children were found to have very high blood lead levels, in many cases above 1000 µg/l. Following these findings, in March 2008 the Senegalese Ministry of Environment removed 300 tons of battery waste and contaminated soil and covered the area with clean sand.

In June 2008, an international team consisting of a clinical toxicologist, an environmental health specialist and an analytical chemist assisted the Senegalese Ministry of Health and Prevention in further health investigations. Medical examinations of children and mothers of deceased children and of randomly selected members of the community (including among people who had never been involved in lead recycling and/or extraction activities) confirmed continuing high blood lead levels ranging from 363 to 6139 µg/l. Furthermore, children whose blood lead level was measured in the earlier investigation, showed increased concentrations, indicating continuing exposure. In addition, evidence of neurological damage, some of which may be irreversible, was observed mainly in children. These findings raised concern that the whole population of NGagne Diaw, estimated at 950 inhabitants, might be intoxicated by lead.

Environmental investigation found that the whole quarter of NGagne Diaw was heavily contaminated by lead as a result of informal lead recycling and extraction activities. Lead concentrations up to 30% were measured outdoors, while concentrations up to 1.4% were measured indoors. Environmental contamination seemed to be limited to this quarter, which has an area of about 350 m by 200 m.

Site visits and interviews revealed that informal lead battery recycling had been taking place since about 1995 on an open area of land in the middle of NGagne Diaw. Over the years this had resulted in extensive lead contamination of the soil. However, towards the end of 2007, lead battery recycling intensified and, in addition, people started to transport contaminated soil from the recycling area to other areas in the quarter to sieve it and extract lead parts. Enriched soil was then packed into bags and stored inside homes to be sold later to a local businessman. Children were seen to play with this contaminated soil. These activities resulted in a massive environmental contamination both indoors and outdoors, and, through inhalation/ingestion of contaminated dust and hand-to-mouth behaviour of small children, in a considerable human exposure to lead for the whole community.

Clean-up operations conducted by the Ministry of Environment in March 2008 contributed to temporarily reducing lead exposure of the population in the area. However, measurements subsequently conducted in the field clearly demonstrated that lead contamination had spread again from untreated areas as a result of daily activities by inhabitants and from the effect of local wind.

KEY POINTS

- Exposure should be stopped as soon as possible. This might involve moving people out of the contaminated area.
- Treatment to aid the body in metabolizing or expelling chemicals should be provided, if feasible (in this case chelation therapy). Special treatment regimes might be necessary for children.
- Systematic screening of the whole population at risk should be considered to identify those in need of therapy.
- Continued medical follow-up for the affected population should be provided.

a http://www.who.int/environmental_health_emergencies/events/Senegal2008_update/en/index.html resources are needed to keep them up to date, which is important for ensuring comprehensive medical follow-up. It is also important to address privacy issues when creating and maintaining registers.

If measures that would restrict the use of land or facilities, or otherwise affect people's livelihoods, have been put in place, resources should be sought to maintain or improve the quality of life. Local authorities should be involved in negotiating for these resources, if appropriate. If important sites, such as play areas for children, or conservation areas are declared "no-go" areas, or if key facilities can no longer be used as a result of contamination, provision of alternative areas and facilities should be a high priority. Also, alternative accommodation for residents should be made available if it is not safe for people to inhabit their homes.

If exposure levels are considered acceptable for preventing acute health effects, but there is either uncertainty regarding whether current exposure levels may be associated with long-term health effects, or else intermittent peaks in exposure levels may be unacceptable, every effort should be made to reduce exposure levels to protect the population, especially vulnerable individuals. If this cannot be done, the exposed or potentially exposed population should be monitored for adverse health effects or chemical-related illnesses.

After the first urgent communications, the public should continue to be provided with specific and timely information regarding appropriate behaviour and safety measures, and should also have access to information that will help them understand the nature of the health effects that may be related to the incident. Mechanisms by which the community can express their concerns are also vital. Consideration should be given to either maintaining or establishing a hotline or other public information resource. This is best organized through a community spokesperson. The community needs to be aware of the measures implemented to prevent a recurrence of the incident. These measures include actions to reduce the probability of another incident, actions to reduce the toxic effects of the incident, and should take into account any lessons that have been learned in the management and control of the incident.

Following some incidents, the individuals affected may choose to take legal actions, primarily to request financial compensation. Hence, the lead agency, together with the other groups involved, should strive to have legal counsel available throughout the rehabilitation process.

Rehabilitation aims to:

- implement remediation and restoration measures for the environment;
- restore the environment to its original state, as it existed before the incident;
- address concerns of the affected community;
- assess and if necessary treat acute health effects;
- restore health care and community services to the levels prevailing before the incident;
- provide evaluation and feedback on incident response;
- monitor for unexpected effects or for potential effects when risk is uncertain;
- continue risk reduction and prevention activities;
- restore trust in and trustworthiness of public agencies.

6.4 PREVENTION OF INCIDENT RECURRENCE

The results of the causative factors analysis and emergency response evaluation described below should be made available to national legislators, the Chemical Incident Management Structure and all emergency planners, so that national legislation and national and local planning activities can benefit from the lessons learned from past incidents.

6.4.1 Causative factors analysis

An essential task following a hazardous chemical incident or near incident, is to take steps to evaluate

CASE STUDY 17: BHOPAL, INDIA – 20 YEARS LATER

More than 20 years after the incident that affected more than 500 000 people, life has still not returned to normal in Bhopal, Central India. Many victims are suffering from long-term illnesses related to the incident. At least 5000 survivors line up every day outside clinics and hospitals to be treated for illnesses related to methyl isocyanate exposure.[a] Long-term health assessments are insufficient. The ambitious long-term health monitoring study led by the Indian Council of Medical Research (ICMR) ended abruptly in 1994 and was handed to the Centre for Rehabilitation Studies (CRS).[b] The CRS is led by the Madhya Pradesh State government, which has no specific expertise in designing health studies. Besides, the CRS has few resources available to do comprehensive epidemiological studies.

Because of ongoing lawsuits, little progress has been made in decontaminating the Bhopal plant site, now under control of the State of Madhya Pradesh. Many chemicals used at the plant were abandoned on the site in 1985 and were still there in 2004, mostly in substandard storage conditions.[c] Remediation of the abandoned facility is the subject of an ongoing civil suit in the US law courts filed by victims of the initial exposure who claim that the chemicals are leaching into the drinking-water of some of the city's poorest neighbourhoods, which are home to more than 20 000 people. The State government was summoned by the Supreme Court of India to supply clean drinking-water to the residents in 2004. In 2006, it announced a scheme to respond to this request that would include the construction of six water tanks and the transportation of safe water from the Kolar dam into pipelines.[d]

In addition to decontamination, victims of the Bhopal incident are still waiting for financial compensation for their losses, be it of their relatives, physical condition or job. Although Union Carbide (purchased by Dow Chemical in 2001) paid US$ 470 million in a civil court settlement, it is still confronting a criminal trial, which is now completing its 17th year.

KEY POINTS

- The follow-up response to a chemical incident should include a long-term health assessment if appropriate.
- Lawsuits can considerably slow down the remediation efforts. The possibility of a law suit should be taken into account while planning the follow-up response.
- Long-term environmental monitoring should be conducted in order to prevent further long-term exposure of the public to the chemical(s) of concern.

[a] Tremblay J-F, Reisch M. Twenty years after Bhopal, compensation still sought by the victims as investigation of accident continues. *Chemical and Engineering News*, 2004, 82:8.
[b] Crabb C. Revisiting the Bhopal tragedy. *Science*, 2004, 306:1670–1671.
[c] Willey RJ. *The accident in Bhopal: Observations 20 years later*. 2006 (http://aiche.confex.com/aiche/s06/techprogram/P35376.HTM).
[d] Bhopal gas victims to get safe drinking water. *The Times of India*, 15 April 2006.

the causative factors leading to the event. The purpose of this analysis is to identify the underlying causes leading to the chemical incident in order to prevent a recurrence. Although this analysis will most likely be done at the national level, local personnel may also play a crucial role in the process, because they have more knowledge of the incident and the hazardous site. Some countries have established independent accident investigation boards, to ensure methodological quality, structure and independence of the investigation to maximize the benefits.[1]

Several tools and analytical methods are available to chemical emergency managers for evaluating the causes of chemical releases. All of them aim to identify a root cause (or multiple root causes) of the chemical incident and identify countermeasures that will prevent a recurrence.

After identifying the causative factors that led to a certain incident or near incident (using the techniques described below, for example), it is important to take corrective actions to ensure that there is no recurrence. During this process, it is important to focus on the positive ways of preventing an incident, followed by effective application of resources to implement preventive measures.

Incident investigation for the purpose described above can be complicated if an incident scene or contaminated products are subject to criminal investigation. Once

[1] Information from World Health Organization. *Assessing the health consequences of major chemical incidents: epidemiological approaches.* Copenhagen, World Health Organization, 1997.

an incident scene has been declared a crime scene, access of health officials may be restricted (for some time). Installation of an independent national incident investigation board with appropriate authority and resources may facilitate access to investigate a crime scene.

Root cause analysis[1] (RCA)

Root cause analysis (RCA) is a process designed for use in investigating and categorizing the root causes of events with health and environmental impacts. Simply stated, RCA is designed to help identify not only *what* occurred and *how* an event occurred, but also *why* it happened, thus preventing recurrence. Root causes are reasonably identifiable and can be controlled; and their identification can allow for the generation of corrective recommendations. RCA involves data collection, mapping out causes, identification of the specific causative event(s) or factor(s), and generation of recommendations. This process can be used to identify not only the causative events, but also those factors which did not contribute to a chemical incident, thus focusing corrective action on the events that led to the incident.

WEB LINKS 9: TEXTBOOKS

> Numerous textbooks have been published on root cause analysis techniques. In addition, the US Department of Energy has a guidance document available at: http://www.management.energy.gov/1602.htm

Critical incident technique

The critical incident technique involves conducting interviews with individuals involved in an incident or near incident, to identify and eliminate hazards.[2] The critical incident technique is a method of identifying errors and unsafe conditions that contribute to both potential and actual injurious accidents within a given population by means of a stratified random sample of participants and observers selected from within this population.

Fault hazard analysis or fault tree analysis

Fault hazard analysis or fault tree analysis is a quantitative technique that provides a systematic description of the combinations of possible occurrences in a system, which can result in an undesirable outcome.[3] The most serious outcome (the chemical incident) is placed at the top of the “tree”. A fault tree is then constructed by relating the sequences of events, which individually or in combination, could lead to the incident. The tree is constructed by deducing the preconditions for the chemical incident, and then repeating this process successively for the next level of events, until the basic causes of the chemical incident have been identified. By assigning probabilities to each event, the probability of a release can be calculated. This method allows chemical emergency professionals to focus resources on preventive measures for the specific causative events that have the highest probability of leading to the release of a hazardous chemical.

6.4.2 Evaluation of the response to the incident

A systematic performance review for the response to a chemical incident or near incident can be conducted in several ways. The time, effort and resources allocated to such a review will vary according to the nature of the incident, the complexity of the response, lessons learned from the last review and the availability of resources. The following three methods can be used in reviewing the overall response to an incident.

After the review process is complete, it is essential to incorporate any lessons learnt into improving the chemical emergency response system. This can include procurement of additional tools, communication or protective equipment that can be used during another incident response. In addition, the information gained during the review process can be used to improve the training process for public health incident responders.

[1] Rooney J J, Van den Heuvel LN. Root cause analysis for beginners. *Quality Progress*, July 2004.
[2] Flanagan JC. The critical incident technique. *Psychological Bulletin*, 1954, 51.
[3] See for example: Harms-Ringdahl L. *Safety analysis, principles and practice in occupational safety*, 2nd ed. Boca Raton, FL, CRC Press, 2001.

Wash-ups

A wash-up is a relatively simple method to conduct a review, which involves a quick rerun of the events of the incident and the response of the chemical emergency responders. Obvious errors, deviations from the chemical incident response plan, and problems in communications are then highlighted in a non-adversarial manner so that participants can learn as much as possible from the actual incident and the rerun. The wash-up is conducted as soon as possible after the incident, while the events are still fresh, and is usually an 'in-house' affair. The lessons learnt should be written up promptly and disseminated widely and eventually factored in to standard audit and training materials.

Evaluations

The goal of an evaluation is to analyse, in a methodical and systematic way, the events of the incident and to assess what impact the response had on the outcome. In particular, questions are asked and judgements made as to the difference in outcomes if there had been no chemical incident response, or if different responses had been made. It is a "what if" exercise. The responses to the incident should be compared to existing operating procedures, and ideally, outside experts should be brought in to add their expertise and a level of objectivity.

Audits

An audit is a similar exercise to the wash-up, but the actual performance is measured against standards. Standards are stated, explicit levels of expected performance, covering qualities such as the speed of response, the presence or absence of minimum levels of equipment, the achievement of minimum or maximum levels of performance. Data from a chemical incident are collected and collated, and compared to the standards. The setting of standards is a complex issue in its own right, and may require compilation of data from previous incidents. All of the actions taken during the public health management of a chemical incident are mapped out, and where available, a standard is identified. Ideally the standards should be established before any incident has taken place, but often this is not possible, in which case retrospective standards can be established. An advantage of establishing standards before an incident has occurred is that the data necessary to measure the performance against the standard can be collected as the incident progresses. In any case, it is important that these standards are established before the audit and are independent of the actual results of the response. Following the audit, judgements should be made as to how well the standards were met, and any areas for improvement should be noted.

6.5 CONTRIBUTION TO THE INFORMATION OF THE INTERNATIONAL COMMUNITY

Important public health lessons can be learned from analysis of an actual incident (or near incident) as well as from any epidemiological study conducted following an incident. Whenever possible, the details of the incident should be written up and published. Reports can be simple descriptions of the incident, epidemiological studies or lessons learned. Reports should be published in peer-reviewed journals, and/or sent to the WHO Collaborating Centre for the Public Health Management of Chemical Incidents and Emergencies,[1] the WHO Collaborating Center for the Epidemiology of Disasters,[2] and/or to other institutions that collect information on chemical and other incidents and emergencies, such as the Agency for Toxic Release Register in the United States (ATSDR)[3] and the MARS database.[4]

In addition, it is essential to use the data obtained during the routine activities discussed in section 3 to continually evaluate and improve the components of a chemical incident response system. These data should make it possible to:

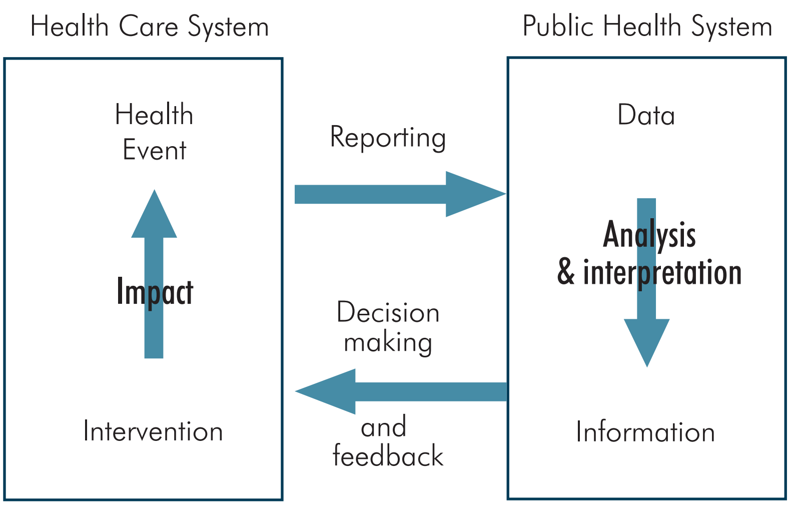
- detect trends in the types of chemicals commonly involved in incidents;

1 http://www.cardiff.ac.uk/medic/aboutus/departments/primarycareandpublichealth/clinical/publichealth/index.html
2 http://www.emdat.be/
3 http://www.atsdr.cdc.gov/HS/HSEES/index.html
4 http://mahbsrv.jrc.it/mars/default.html

- provide estimates of the magnitude of morbidity and mortality related to the chemical incidents under surveillance;
- stimulate epidemiological research likely to lead to control or prevention;
- identify risk factors associated with the occurrence of chemical incidents;
- permit assessment of the effects of control measures;
- lead to improvements in the practice of health and environment officials who are involved in responding to an incident;
- perform analyses to pinpoint what additional expertise, training, resources, and facilities are needed to deal with incidents; and
- stimulate governments to initiate proper incident control mechanisms.

Figure 10 shows how the public health system and the health care system can work together to use surveillance data.

FIGURE 10: PUBLIC HEALTH SURVEILLANCE: GENERAL PRINCIPLE[a]



[a] Diagram from the UK Health Protection Agency: http://www.hpa.org.uk/webw/HPAweb&Page&HPAwebAutoListName/Page/1158934607635?p=1158934607635.

CASE STUDY 18: EXPLOSION OF A FIREWORKS FACTORY – ENSCHEDE, THE NETHERLANDS

On 13 May 2000, two huge explosions occurred in a warehouse storing fireworks in a residential area of Enschede, the Netherlands. The blast was felt up to 30 kilometres away. The incident killed 22 people, including four fire-fighters and left 944 persons injured, many seriously. Four hundred homes were totally destroyed, while another 1000 were damaged.

While the exact cause of the incident is still unknown, subsequent investigations showed that the owner of the warehouse stored more fireworks than permitted in the warehouse and that the majority of them were of a much heavier class than allowed.[a] Overall, safety regulations seemed not to have been followed with great care. This was made possible by insufficient attention and inspection by the local government agencies.

The follow-up response to the incident was characterized by an in-depth analysis of the causative factors of the incident, which led to the adoption of new regulations regarding fireworks, such as new labelling requirements and more stringent safety distances.[b] The recovery was also characterized by a large assessment of public health that was started two to three weeks after the incident. The assessment comprised a general questionnaire survey focused on physical stress, and on health and emotional problems, as well as collection of blood and urine samples, in order to detect any harmful substances that could still potentially be found in the body.[c] Any organization or agency that worked in the health care sector was involved in the assessment. The results were communicated to the public, together with details of information contacts. The public health monitoring continued for several years and its results were also discussed among health-care professionals and policy-makers. Finally, the public health assessment resulted in numerous scientific publications.

KEY POINTS

- If necessary and appropriate, the follow-up response should include a public health assessment. The results of such a study can be very helpful for managing long-term health problems resulting from an incident and should be communicated to the international chemical incident management community by means of publication in peer-reviewed journals.
- The results of monitoring activities, whether related to public health or the environment, should be communicated to the public and discussed with policy-makers.
- After a chemical incident, an in-depth analysis of the causes of the incident should be done in order to prevent the occurrence of similar events.

[a] *Emergency and Disaster Management Inc. Final Report* (http://www.emergency-management.net/enschede1.pdf)
[b] European Commission Joint Research Center. *Pyrotechnic and explosive substances and the Seveso II Directive.* Seminar Proceedings, September 2000, March 2001.
[c] Ministry of Health, Welfare and Sport. *Definitive results health inquiry, fireworks disaster.* Enschede (May–June 2000).

GLOSSARY

Note that the definitions given below apply to the terms as used in this manual. They may have different meanings in other contexts.

a

acute	occurring over a short time
acute effects	effects that occur rapidly following exposure and are of short duration
acute exposure	chemical exposure of less than 14 days duration
agent	a substance that exerts some effect or force
at risk	where an individual or population is threatened by a chemical release

b

biomarker	a chemical, biochemical, or functional indicator of exposure to (or the effect of exposure to) an environmental chemical, physical or biological agent

c

chemical agent	a type of toxic agent that can produce an adverse biological effect
chemical incident	an uncontrolled release of a chemical from its containment
chronic	an event or occurrence that persists over a long period of time

chronic effects	effects that develop slowly and have a long duration. They are often, but not always, irreversible. Some irreversible effects may appear a long time after the chemical substance was present in the target tissue. In such cases, the latent period (or time to occurrence of an observable effect) may be very long, particularly if the level of the exposure is low
containment	to control and limit the spread of a harmful substance
contaminant	a substance that has the potential to pollute
contaminated	the presence of a substance in or on an environmental medium or surface that has the potential to pollute. It usually applies to situations where there is a danger to people or animals of secondary exposure

d

decontamination	to make safe by eliminating poisonous or otherwise harmful substances, such as noxious chemicals or radioactive material, from people, buildings, equipment and the landscape

e

emergency	an incident that has passed the control capability of emergency service providers
emergency responders	all the services that work together, off-site and on-site, to deal with an incident – fire, police, ambulance, water, food, port, public health/ environmental health
environment	the environment consists of all, or any, of the following media: the air, water and land. The medium of air includes the air within buildings and the air within other natural or man-made structures above or below ground
environmental epidemiology	epidemiological studies on the health effects of environmental exposures
environmental hazard	a chemical or physical agent capable of causing harm to the ecosystem or natural resources
environmental health	comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social, and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially affect adversely the health of present and future generations
epidemiology	the study of the distribution and determinants of health-related states or events in populations and the application of this study to control health problems
exposure	contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term (acute exposure), of intermediate duration, or long-term (chronic exposure)

exposure limit	a general term implying the level of exposure that should not be exceeded

h

hazard	the latent property of a substance which makes it capable of causing adverse effects to people or the environment under conditions of exposure
hazardous site	site that could present dangers to public health and the environment due to the presence of contamination
health impact assessment	a practical approach used to judge the potential health effects of a policy, programme or project on a population, particularly on vulnerable or disadvantaged groups. Recommendations are produced for decision-makers and stakeholders, with the aim of maximizing the proposal's positive health effects and minimizing the negative health effects

i

incident	see chemical incident

l

latent period	time from exposure to occurrence of an observable effect

m

mitigation	all activities aimed at reducing the health, environmental and economic impact of a chemical incident once the incident has occurred
morbidity	the relative incidence of a particular disease. In common clinical usage, any disease state, including diagnosis and complications, is referred to as morbidity
morbidity rate	the rate of disease or proportion of diseased people in a population
mortality	the ratio of deaths in an area to the population of that area, within a particular period of time. (The death rate in a population or locality.)

p

pathway of exposure	the route that a chemical takes through environmental media from its release to the portal of entry to the human body
personal protective equipment	includes all clothing and other work accessories designed to create a barrier against workplace hazards. Examples include safety goggles, blast shields, hard hats, hearing protectors, gloves, respirators, aprons, and work boots

pharmacokinetics	how the body deals with a particular chemical or drug
pollution	the presence in a medium of a pollutant(s) in concentrations great enough to interfere, directly or indirectly, with a person's comfort, safety, health or enjoyment of his or her property
portal of entry	the point at which a chemical enters the body – skin, eyes, lungs or digestive tract
prevalence	the number of cases in a defined population at a specific point in time
primary contamination	direct contact of the person with the chemical contaminant
public health chemical incident	an incident in which two or more members of the public are exposed to a chemical or are threatened with exposure to a chemical
public health surveillance	the ongoing systematic collection, analysis, and interpretation of data relating to public health

r

rehabilitation	the restoration of normal functioning of people and communities
relative risk	synonymous with risk ratio
release	accidental or intentional escape of toxic substance into the environment
remediation	for the purpose of this document, remediation is the process of making the environment safer and cleaner – as defined by national regulations – after it has been contaminated by one or more hazardous chemical(s)
restoration	the process of returning the environment to its original state
risk assessment	the identification of environmental health hazards, their adverse effects, target populations and conditions of exposure. A combination of hazard identification, dose–response assessment, exposure assessment and risk characterization
risk communication	the process of sharing information and perceptions about risk. It should be a two-way interaction in which experts and non-experts exchange and negotiate perceptions relating to both scientific and community values and preferences
risk ratio	the ratio of the incidence of a disease among exposed people to the incidence of the disease among unexposed people

s

secondary contamination	the transfer of a chemical from a contaminated person (usually from their clothing, skin, hair, or vomitus) to personnel or equipment, directly or by emission from a contaminated surface
substance	any natural or artificial matter, whether in solid or liquid form or in the form of a gas or vapour

substance hazardous to health	a material that is toxic, corrosive, an irritant, carcinogen, mutagen, a biological agent, dust in substantial concentrations in the air, or any other material that is injurious to health
surveillance	see public health surveillance

t

toxic	poisonous
toxic agent	anything that can produce an adverse biological effect. It may be chemical, physical, or biological in form. For example, toxic agents may be chemical (such as cyanide), physical (such as radiation) or biological (such as snake venom)
toxic effect	a result produced by the ingestion of, or contact with, toxic substances
toxicity	the capacity of a substance to cause injury to a living organism. A highly toxic substance will cause damage in small quantities, while a substance of low toxicity will need large quantities to produce an effect. Toxicity is also dependent on the portal of entry, the time frame of exposure and the latent period
toxic substance	see toxic agent
toxicology	the study of the harmful effects of substances on humans and animals
triage	the assessment of the clinical condition of exposed individuals with designations of priorities for decontamination, treatment and transportation

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