3. THE ROLE OF THE HEALTH SECTOR IN RESPONDING TO CHEMICAL ACCIDENTS

3.1 Definitions

For many chemicals, the biological and/or health effects following acute exposure to high concentrations can be quite different from those produced by low-level chronic or intermittent exposure. For example, while the acute effects of exposure to benzene consist predominantly of central nervous system toxicity, low-level and chronic intermittent exposure can result in bone marrow depression.

Definitions of acute and chronic (intermittent) exposure have been derived mainly from animal experiments. However, under experimental conditions it is far easier to determine the duration of exposure than in the case of chemical accidents involving humans. Although acute exposures have been defined as being of a duration not longer than 24 hours, when a chemical accident occurs the exact time at which exposure begins is often difficult to define. First, one needs to be clear whether exposure has in fact occurred; and if so, for what period of time people were exposed.

Chronic (intermittent) exposure may occur where there is environmental contamination (pollution) or where toxic chemicals are present in the food chain. In these situations, however, the problem tends to be an acute one and the relevant authorities will need to take whatever action is necessary. Apart from measures to reduce exposure and, if possible, avoid further exposure, formal risk assessment is necessary to determine whether the exposure will result in any adverse health effects, either currently or in the future. During the period of that risk assessment, individuals with problems and complaints which they attribute to the exposure should have the opportunity to consult a physician who can evaluate their symptoms and signs and supply them with information about a possible link to the exposure.

3.2 Routes of exposure

In most cases, symptoms and signs exhibited by chemical accident victims are immediate or are delayed for only one or two hours. In some cases, however, the features of toxicity may appear days, weeks, months or even years after the acute exposure. Symptoms and signs may be local (eyes, skin, respiratory tract, gastrointestinal tract), systemic or both. The most common acute systemic features are expressed in the central nervous system (excitation, depression), circulatory system (vasodilatation, arrhythmias, cardiovascular depression), gastrointestinal tract (malaise, vomiting, diarrhoea), and in the blood (methaemoglobinaemia, haemolysis). Delayed features may be seen in any organ system, but most commonly in the respiratory tract (delayed-onset pulmonary oedema), kidneys, liver and blood-forming organs.

The most common type of exposure in the case of major chemical accidents is inhalation of gases stored under pressure, which spread rapidly and over a wide area. Other likely routes of exposure in this context are the eyes and skin. Ingestion of a toxin is more likely to occur if drinking water or food have been contaminated, either by accident or deliberately.

3.2.1 Eye exposure

Eye injuries affecting a number of individuals are most likely to result from gases, vapours or dusts, though splashes of liquids into the eye may occur in an industrial accident or in a road or railway accident where the toxic substance is widely disseminated. Eye injuries in these situations will often be combined with skin lesions, respiratory tract injuries or systemic poisoning. Eye damage is usually the result of [lachrymatory action,] corneal epithelial injury or keratitis. These effects may be immediate or delayed. Some substances cause severe and deep injuries almost immediately, while others cause only superficial damage which is reversible.

3.2.2 Skin contact

Skin exposure to toxic agents may cause local injury alone, or local injury and systemic poisoning. Systemic poisoning may even be the only feature, as a result of absorption through intact skin. Although the skin is usually an effective barrier to toxic chemical absorption, intact skin behaves in a manner similar to other cellular membranes. Toxic agents penetrate the skin at rates determined by their lipid solubility: lipid-soluble substances are readily absorbed through the skin. Organic solvents used as vehicles for certain industrial chemicals may also enhance skin absorption. Inflammation, rubbing or other causes of increased skin blood flow will further increase chemical absorption. Skin damage seen, for example, in the case of corrosive burns may destroy the natural barrier properties of the skin. As a result, non-soluble lipid substances may be absorbed and cause systemic poisoning. Even a first degree burn may impair or destroy the barrier properties of the skin.

Damage resulting from skin-chemical contact is usually a chemical or corrosive burn, and may be classified in the same manner as thermal burns (see **Table 3.1**). Characteristic lesions are seen after acid or alkali burns. Only the superficial layers of skin are affected in mild cases of chemical burns due to these types of agent, while in severe cases all skin layers and possibly also the underlying tissue are damaged. Local damage is most often seen directly after skin exposure to the toxic agent, but in some situations the initial signs of local damage may be lacking though advanced local damage appears later. For example, phenol and phenol-like compounds initially anaesthetise the skin, thus masking the typical sign of local damage -- pain. After skin contact with low concentrations of hydrofluoric acid solutions, initial signs of skin damage (and hypocalcemia) are lacking, but several hours later signs of skin damage and subcutaneous tissue damage appear. Fluoride ion penetrates the skin and interferes with cellular membrane calcium ions, causing cellular necrosis. However, strong hydrofluoric acid solutions produce an immediate local skin burn.

Systemic poisoning after skin absorption through intact skin is most likely to occur following contact with lipid-soluble substances such as the organophosphates. Once skin absorption has occurred, clinical features of toxicity appear after a symptom-free interval of minutes, hours or even days, depending on the type of damage and target organs. Features of central nervous system toxicity, such as excitation, convulsions, CNS depression and coma, appear soon after the exposure, as do cardiovascular signs of toxicity. Methaemoglobinemia and hemolysis may also be early features of toxicity. Signs of renal and hepatic damage are not usually present until one, two or more days after exposure.

Table 3.1 Classification of corrosive burns

For exposure to corrosive substances with skin damage, classification can be made according to the principles applying to thermal burn injuries (after Arturson et al.)

Group 1 (life-threatening injury):

Dermal and full-thickness injuries exceeding 50% of body surface area.

Group 2a (severe injury):

Full-thickness injuries of 10-50% or dermal injuries of 20-50% of body surface area.

Group 2b (moderate injury):

Full-thickness injuries of 2-10% or dermal injuries of 10-20% of body surface area.

Group 3 (mild injury):

Full-thickness injuries of 2% of body surface area or dermal injuries of less than 10% of body surface, or epidermal injuries.

3.2.3 Inhalation

In chemical accidents involving the exposure of a large number of persons, the main route of exposure will be by inhalation, of gases, fumes, aerosols or respirable dust. The result of exposure of the airway to chemicals may consist of local effects on the mucous membranes at different levels, as well as of other effects due to absorption through the lungs. Immediate symptoms may arise, as well as symptoms which appear after a (more or less) symptom-free (latent) interval.

Toxic inhalants (gases, vapours, aerosols and dusts) are characterised by their physical properties and pathophysiology effects, which in turn determine the clinical findings on presentation. Five categories of noxious agent are recognised: irritants; systemic poison; combined irritants and systemic poisons; inert gases; and hot gases.

Irritant inhalants produce toxicity by causing mucosal damage of the respiratory tract. The location and severity of the injury will depend upon the reactivity, concentration, particle size and water solubility of the substance and on duration of exposure. Previous underlying disease, especially of the respiratory tract, plays an important role in this context. It is important to distinguish two groups of irritant gases, i.e. (i) those causing immediate features of toxicity and (ii) those causing only minor and/or no immediate symptoms or signs of toxicity.

Inhalants that are highly water-soluble (for example, acids, alkali, ammonia, hydrogen chloride, hydrogen fluoride) dissolve in the water phase of the upper respiratory tract mucous membranes and typically will not reach the lower respiratory tract unless exposure is prolonged or high concentrations of gas are inhaled. These gases usually produce immediate symptoms such as watering of the eyes, rhinitis, pharyngitis, cough and, in severe cases, laryngeal oedema.

Following exposure to high gas, vapour or dust concentrations, reflex circulatory or respiratory arrest may occur. Where there is prolonged exposure, there may be damage to the lower respiratory tract. This is even more likely to occur with the chemicals that are intermediate in their water-solubility (for example, halogen gases, hydrogen halides, phenol, sulphur dioxide). Otherwise, it is mainly the inhalant chemicals of low water-solubility that damage the lower respiratory tract in low concentrations and following short exposure, causing pneumonitis, alveolitis and pulmonary oedema, sometimes without any significant effects on the upper respiratory tract or eyes (for example, chlorine, hydrogen sulphide, isocyanates, mercury vapour, nitrogen oxides, phosgene).

Usually, early respiratory symptoms are prominent, giving an indication of the severity of exposure. However, attention should be paid to the fact that initial signs of respiratory tract damage may be lacking in the case of, for example, nitrogen oxides and phosgene. Following the onset of initial symptoms, there is usually a latent period during which the patient suffers little discomfort. This period may last between 30 minutes and 24-48 hours, and rarely 72 hours. This latent period is followed by the development of respiratory symptoms and pulmonary oedema due to increased capillary permeability. In severe cases, pulmonary oedema may appear during or shortly after the chemical exposure.

Apart from chemical irritation, other effects on the respiratory tract may result. Isocyanates, for example, cause an asthma-like syndrome. This asthma-like syndrome has two different mechanisms. One is attributable to the fact that isocyanates are sensitisers of the respiratory tract, giving asthmatic symptoms, particularly after repeated exposure to low concentrations of the isocyanate. The other mechanism is that isocyanates may alter the biological response to beta-adrenergic stimulation or may induce local histamine release, thereby causing bronchoconstriction that does not appear until after a latent period of several hours.

Chemicals that are inhaled may also cause *systemic poisoning* without any respiratory tract symptoms. Symptoms of systemic poisoning vary according to the toxic substance and its target organs. Almost all types of toxic damage may be seen, and symptoms and signs may be immediate or delayed. The most prominent immediate features are those arising from the central nervous and cardiovascular systems. Hydrogen cyanide and hydrogen sulphide, for example, block cellular utilization of oxygen, causing cellular hypoxia and impairment of the central nervous and circulatory systems almost immediately. This is also true of carbon monoxide, which in addition prevents delivery of oxygen to the cell by blocking haemoglobin oxygen transport capacity.

Organophosphates are potent inhibitors of cholinesterases, resulting in accumulation of acetylcholine at synapses in the nervous system and at myoneural junctions, giving rise to cholinergic poisoning. Volatile hydrocarbons are narcotics causing central nervous system depression. Halogenated hydrocarbons also sensitise the myocardium to endogenous and exogenous catecholamines, causing arrhythmias, predominantly ventricular, and sudden death due to ventricular fibrillation. Inhalation of oxidizing agents (nitrites and nitrobenzene) causes methaemoglobinaemia. Aside from carbon monoxide, gases of combustion may include hydrogen cyanide (from polyurethane, wool, silk, etc.) and irritant gases (nitrogen oxides, hydrogen chloride, sulfur dioxide, isocyanates, acrolein, ammonia etc.).

Toxic inhalants that are *both irritants and systemic poisons* also exist: for example, hydrogen sulphide, ozone, acetylene and some metal fumes. Biologically *inert* gases are not toxic in themselves, but in high concentrations or in poorly ventilated rooms they displace oxygen from air and thereby cause hypoxia. Gases of this type are hydrogen, carbon dioxide, methane and liquid gas. Inhalation of *hot gases* may cause thermal burns to the mucous membranes of the entire respiratory tract; acute onset of laryngeal oedema may occur after a latent period of hours.

3.2.4 Ingestion

Following ingestion of corrosive, oxidizing or coagulative substances, there is a risk of local injury to the gastrointestinal tract. Low-viscosity substances such as petroleum distillates of the kerosene type are associated with a risk of aspiration into the airway with consequent effects on the lungs. A risk of systemic poisoning after ingestion of a toxic substance is of course present if the substance is absorbed through the gastrointestinal tract.

Poisoning may also occur through the ingestion of chemically contaminated food or water, or even pharmaceuticals. Large numbers of victims may be involved.

Table 3.2 Examples of combustion products

Combustion product:	Material:
Carbon monoxide	Most materials
Hydrogen cyanide	Wool, cotton, silk, polyurethanes
Nitrogen oxides	Nitrocellulose, polyamides
Hydrogen chloride	Polyester resins (some)
	Polyvinyl chloride (PVC)
	Chlorinated hydrocarbons
Sulphur dioxide	Sulphur compounds, coal, mineral oil
Isocyanates	Polyurethanes
Acrolein	Petroleum products
Phosgene	Polyvinyl chloride
Ammonia	Polyamides, wool, silk, phenol resins
Hydrogen fluoride	Teflon (polytetrafluoro ethylene) and other fluoride-containing compounds
Bromic acid	Bromine-containing compounds

3.3 *First actions*

3.3.1 Rapid identification of chemicals

An attempt should be made at once to identify the chemical(s) involved in the accident. Hospitals, Poisons Information Centres and chemical response centres are among the organisations that should receive this information without delay, together with details on the type of accident (chemical spill, liquid or gas leakage, fire, etc.).

If the chemical(s) concerned have not been (or perhaps cannot be) identified, knowledge of the general category to which they belong (solvents, pesticides, irritant gases), together with information on the symptoms of the victims, can help responders decide on the appropriate course of action. In the case of fires, a number of combustion products may be formed (see **Table 3.2**).

Health care units should use the information provided on the chemicals involved, etc. to make an early determination of possible toxic effects and mechanisms (local or systemic toxicity, acute or delayed toxicity), as well as whether any specific therapy is relevant or whether symptomatic care will be sufficient treatment.

The health care professionals at or near the scene of the accident should become part of the information chain. The information, which needs to be updated regularly, should contain:

- all the information available to first responders;
- the number and type of patients expected, and their degree of exposure;
- any new information concerning the type of chemicals involved and, where measured, the concentrations involved;
- additional medical information from Poisons Information Centres and hospitals, such as symptomology, antidote therapy or specific treatment;
- the registration (triage) system used (for example, contamination, duration of exposure, current location, medical treatment already given).

3.3.2 Triage principles

Triage is a process that takes place essentially at the site of an accident or at a hospital. It consists of the assessment and classification of the medical conditions of patients, and of the designation of priorities for treatment and transport to hospitals or other treatment facilities.

Triage at the site of a chemical accident is an important medical task. For chemical accident victims, it should follow the rules that apply generally to emergency situations. The point in the treatment chain at which triage is performed needs to be considered in relation to available resources. It is always important for triage to be a continuous process. Each victim should be re-evaluated at regular intervals, as the victim's condition may change as will available resources.

Table 3.3 Classification of irritant gases

For exposure to irritant gases, the severity of clinical features of toxicity may be graded as follows (after Sörbo):

Group 1 (life-threatening injury):

Injured persons with intense irritant-induced cough, respiratory insufficiency, and systemic effects.

Group 2 (severe injury):

Injured persons with strong irritant-caused cough, respiratory difficulties, but no systemic effects.

Group 3 (mild injury):

Injured persons with moderate or slight irritant-caused cough, eye symptoms/signs and, possibly, headache.

As a rule, children are more sensitive to toxic substances (because of more rapid metabolism and circulation and less subcutaneous fat). They should normally, therefore, be given higher priority for medical care.

If the emergency is limited to a chemical accident, the injury profile will be the same for all injured persons though the degree of severity will vary. This can simplify both triage and provision of treatment, as both the classification of the severity of injuries and the treatment of the injured can largely be standardised. For example, in the case of persons exposed to corrosive substances or irritant gases there are criteria for classifying the degree of severity of injury (see **Tables 3.1 and 3.3**, respectively).

In the case of fires, the toxic and thermal damage may complicate the assessment and treatment of victims, as may also trauma associated with toxic exposure.

3.3.3 Treatment principles

The treatment of acute poisoning is based on four main principles that may be utilised to varying degrees, depending on the circumstances of the exposure and the characteristics of the toxic agent. These principles are: (i) the removal of the toxic agent to prevent further local damage or absorption into the body; (ii) symptomatic and supportive therapy; (iii) specific ("antidotal") therapy; and (iv) enhancement of (poison) elimination.

Maintaining vital functions (for example, by preventing airway obstruction, assisting ventilation, replacing fluid losses) is of obvious importance. Removal of the toxic agent to prevent further local damage or absorption into the body is also of crucial importance in the initial treatment of victims at a chemical accident site. However, decontamination should never be allowed to delay treatment aimed at maintaining vital functions and should preferably take place before transportation to hospitals or other treatment facilities. Symptomatic and supportive therapy is always applicable in the treatment of poisoning. In the majority of instances, this is the only type of treatment required to permit full recovery from poisoning.

As stated above, classification of severity and treatment can be standardised, at least to a certain extent. Aside from first aid, there are instances where specific treatment with, for example, antidotes may profoundly influence the outcome of the poisoning. However, antidotal therapy is effective in reducing morbidity and mortality of only a limited number of types of poisoning (see **Table 2.1**). A universal antidote does not exist, and antidotal therapy should only be used where there are specific indications. It may, however, need to be started before the injured person is transported to a hospital or other treatment facility. In certain circumstances, it can be delegated to health-care personnel with non-medical training - for example, instructions can be given that certain specific measures should be employed if victims show certain characteristic features of toxicity.

Following exposure to some chemicals, victims and equipment may become contaminated. When caring the injured, the rescuer(s) may be exposed to them if not properly protected or if the injured person has not been properly decontaminated beforehand. Transport vehicles may become contaminated, and sometimes unusable for long periods of time, if contaminated persons are transported in them. Similarly, large areas of hospitals may become unusable because of the presence of contamination. This may be the case, for example, when accidents involve ammonia, which is extremely pungent and persistent.

Procedures for decontamination of victims may include sluicing with copious quantities of water and brushing off powders, and removal of contaminated clothing. These decontamination procedures should be carried out as soon as possible. In some emergency situations, decontamination may be an essential part of life-saving first aid. In some other emergency situations, decontamination may aggravate the injury or delay life-saving efforts. The decision whether to decontaminate a victim should be based on the type and severity of the injury and the nature of the chemical contaminants. If decontamination does not interfere with essential treatment, it should be performed. If decontamination cannot be performed, the victim should be wrapped in blankets, plastic, or rubber to reduce contamination of other personnel, and off-site emergency medical personnel should be alerted to the potential contamination, or to specific decontamination procedures.

3.3.3.1 Eye exposure

Immediate or "first aid" decontamination of eyes should be carried out with the utmost speed, usually by flooding the exposed eye with water to reduce damage from surface exposure to chemicals. For continuing irrigation, ordinary tap water or physiological saline solutions are the first choices. Time should not be wasted in looking for special irrigation fluid.

Beginning dilution and flushing as soon as possible after injury is especially critical following caustic exposure. Transportation to a hospital should not be considered as being more important than thorough on-site irrigation. As eye pain causes blepharospasm, the victim needs assistance in keeping the eyelids open. A topical anaesthetic will facilitate adequate eye irrigation and make the patient more comfortable. Common practice is to irrigate for 15-30 minutes to be sure of thorough cleansing. However, if the nature of the chemical contaminant is known definitely, the irrigation used should be adjusted accordingly. For severe alkali burns, irrigation should be continued for some time, initially for at least 15-30 minutes and repeatedly thereafter for several hours. For acid burns, irrigation should be performed for 15 minutes; for minor irritants, irrigation for a few minutes is usually sufficient.

Despite the theoretical advantage of using special agents for neutralizing certain chemicals, this type of treatment has seldom provided a significant advantage over immediate irrigation with water or saline, both of which are usually much more readily available for first aid treatment.

All corrosive burns of the eye should be followed up by a formal ophthalmological examination.

3.3.3.2 Skin contact

Following exposure of the skin to toxic chemicals, flushing of *all* areas of potentially contaminated skin with copious amounts of water should be commenced as soon as possible. Contaminated clothing, shoes, wrist watches and jewellery should be removed to facilitate adequate flushing and saved in closed bags.

Note that *copious* amounts of water should be used, especially when heat production is likely to be pronounced, for example following application of water to strong acids such as sulphuric acid. Flushing with water should be continued for at least 15 minutes. Following exposure to yellow phosphorus, the contaminated part of the body should be kept underwater or dressed with wet dressings, as yellow phosphorus ignites in the air.

After adequate flushing, the skin should be washed thoroughly with soap (non-abrasive) and water, especially where there is a risk of chemical absorption through the skin. After skin exposure to corrosives, the risk of severe fluid loss should be considered and where appropriate the victim should be given intravenous fluids at an early stage.

In some cases, application of an antidote to the skin is of crucial importance. For hydrofluoric acid burns, calcium gluconate gel should be applied. Fluoride ion is then bound to the calcium in a stable, inert complex. thereby preventing the fluoride ion from penetrating the skin and causing severe tissue damage and possible systemic poisoning. In the case of phenol, polyethylene glycol should be used as a cleansing solvent because phenol is poorly soluble in water. For yellow phosphorus, a mixture of potassium permanganate and sodium bicarbonate solutions (or copper solution) may be used to reduce the toxic effect.

3.3.3.3 Inhalation

In the event that irritant or toxic gases are inhaled, exposure should be terminated as soon as possible. Note that the rescuer may need protective clothing and a protective breathing mask.

Following exposure to *irritant gases*, the victim should rest, if possible in a semi-recumbent position to take account of the possibility of pulmonary oedema developing. Oxygen should be administered as soon as possible. Physical activity and hypoxia increase the risk of pulmonary oedema. Apart from optimal symptomatic and supportive therapy, including bronchodilators (by inhalation and systemically) and ventilatory support, administration of corticosteroids by inhalation and systematically is commonly recommended as soon as possible to minimise pulmonary damage. However, it should be noted that this form of therapy remains controversial and that no controlled studies to demonstrate its clinical efficacy are available.

Following exposure to gases that produce *systemic poisoning*, treatment should be guided by the specific toxicant inhaled and the victim's symptoms and signs of toxicity. If the victim is unconscious, oxygen should be given. In addition to being a form of supportive therapy, oxygen reduces the toxicity of carbon monoxide and probably that of hydrogen cyanide and hydrogen sulphide also. Additional specific treatment, such as antidotal therapy, is of critical importance in some types of poisoning, such as that due to hydrogen cyanide, organosphosphates, heavy metals and methemoglobin-forming agents (nitrites, nitrobenzene) and should preferably, when applicable, be given promptly at the site of the accident.

3.3.3.4 Ingestion

Following ingestion of an unknown substance that may involve a risk of poisoning, some advocate that one to two glasses of water or a demulcent agent are given. Emesis should never be induced until it is certain that this measure is suitable. Emesis should never be induced in persons whose general condition is affected (circulation, respiration, consciousness), or if there is a risk of seizures, or following ingestion of corrosive substances or petroleum distillates (mainly of the kerosene type). In many cases, peroral administration of activated charcoal may be indicated to adsorb the toxicant, thereby preventing absorption from the gastrointestinal tract. Therapy is otherwise symptomatic and supportive, but in certain cases antidotal therapy may be indicated -- for example, in the event of intoxication with cyanides, organophosphates and arsenic.

3.3.4 Provision of medical assistance and decontamination

3.3.4.1 At the accident site

In addition to first responders from the police and fire services and from ambulance services (including paramedics), medical personnel may be sent to the accident site. The purpose of initial care given at the accident site is to give patients the treatment needed so they are in the best possible condition for transporting to a hospital or other treatment facility. This is especially important where patients may have to be transported considerable distances, or in mass casualty situations where moving victims to treatment facilities may take a long time because of the large number involved.

In some cases, it is justifiable to introduce more specific treatment even before victims are taken to a hospital or other treatment facility, for example with antidotes and other drugs.

Medical personnel should, in principle, never enter the accident area. They should always work in a safe place well-removed from this area. In those instances where decontamination is necessary, victims should always be adequately decontaminated before being taken to the casualty assembly point.

In addition to general first aid measures such as airway protection, parenteral fluids, pain relief, skin and eye irrigation, etc., it may be necessary to begin other treatment at the accident site. For this reason, special equipment and drugs should be made available there, as necessary.

A decontamination station should be set up in the immediate vicinity of the access point to the inner cordon, so that contaminated victims (and rescue personnel) can be sluiced liberally with water Plenty of *warm* water is needed for this purpose. Personnel from rescue services/fire services are often the best people to decontaminate the injured before they are taken to an assembly point. Medical personnel may be required to assist in decontamination. In that case, it may be necessary for them to have personal protective equipment.

For decontamination, access is required within the accident area to large quantities of warm water so that victims do not become chilled unnecessarily. Contaminated clothing, shoes, etc. should be removed as soon as possible. Therefore, clothes, blankets, etc. for a large number of people need to be available. Preferably, the injured should be decontaminated before they are moved to assembly points.

Decontamination personnel may also of course need to wear suitable protective equipment.

The responsibility for setting up decontamination stations at the accident site needs to be allocated (probably to rescue or fire services).

3.3.4.2 During transport

According to their clinical features of toxicity, a priority classification can be made for the transport of victims to hospitals (or other treatment facilities). In case of exposure to agents with a possible latent period prior to the onset of toxicity, those who were most exposed should be transported to hospitals for clinical observation. Hospitals need to have adequate mechanical ventilation equipment.

Before and/or during transport, the receiving hospitals should be informed as far as possible of the general condition of the patients prior to their arrival. The hospitals can then obtain information about specific treatment from the poison information centre. Severely injured patients should be transported after initial stabilization, and some preliminary decontamination should be considered. Hospitals need to know in advance whether further decontamination still needs to be performed

During transport, initial therapy should continue (oxygen, ventilation, parenteral fluids, pain relief, etc.). Victims should preferably not be transported to hospitals or other treatment facilities before they have been decontaminated, if decontamination is required. However, if this is impossible and it is necessary to transport a contaminated patient, the vehicle windows should be left open so that there is complete ventilation. In this way, the possibility that the vehicle will become contaminated is reduced. Accompanying personnel should wear suitable protective equipment. Before a contaminated ambulance (or equivalent vehicle) is used again, it should be decontaminated.

Equipment for eye irrigation should be available in ambulances and other vehicles transporting victims exposed to chemicals.

As victims may vomit while being transported, the necessary provisions should be taken to avoid spillage in the vehicle (for example, by having available basins, towels, plastic bags or other containers).

3.3.4.3 At hospitals and other treatment facilities

Hospitals and other treatment facilities need to put their emergency response plans into effect the moment that they are informed that a possibility exists that patients will arrive. They can combine information received from the medical co-ordinator at the site with information from the Poisons Information Centre. It is desirable that protocols supplied by the Poisons Information Centre be followed, particularly if patients are taken to a number of hospitals.

Medical assistance teams can assist in the admission of groups of people. However, experienced teams of this nature do not exist in every country. It is important that any evaluation and treatment follows the same protocol for all patients.

Following the arrival of patients, continuity of treatment based on vital signs is the first priority. If patients still need to be decontaminated, contamination of medical personnel should be avoided. Following initial stabilization, a full clinical examination should be performed, as well as any additional investigations required (for example, X-rays, ECG, EEG, laboratory analyses). Samples should be taken for analysis in accordance with agreed protocols. Specific and supportive treatment should be continued.

In general, the treatment of victims exposed to chemicals follows generally accepted principles for the management of emergency situations. However, these principles need to be extended and adjusted to take account of the special conditions that obtain following chemical accidents.

Before a patient who has been exposed to chemicals is admitted to a hospital, decontamination should have been performed whenever necessary, preferably outside the emergency room. Otherwise, if a patient who has not been decontaminated following exposure to, for example ammonia or phenol, is brought into an emergency unit, this unit may be rendered unusable for a considerable period of time thereafter. Depending on existing ventilation equipment, other parts of the hospital may also become unusable.

In cases of exposure to irritant gases, a large number of persons may require ventilation. The hospital should have made an inventory of available ventilators, or have determined where or how to obtain additional equipment, as well as personnel to perform manual ventilation. Plans should also be made for sending patients to other hospitals or facilities where this equipment is available, if necessary.

Following exposure to, for example, irritant gases a number of relatively unaffected persons may need to be placed under observation for one or more days. Plans should be made for setting up suitable observation units in, for example, hotels, schools, etc.

In cases of exposure to corrosives, a large number of persons may require treatment for chemical burns. Plans that already exist for caring for a large number of victims with thermal burns should then be implemented.

Following exposure to a limited number of chemicals, specific antidotal therapy may be required. For this reason, emergency (disaster) stocks of antidotes should be available in every region. **Table 2.1** lists some antidotes and other drugs that may be of value in the event of a chemical accident.

If the hospital and/or the transport route from the accident area to the hospital lie within the accident area, it may prove impossible to transport the injured for some time. Alternative premises such as schools, sports facilities, tents, etc. to which the injured may be taken, and where more or less advanced medical care can be provided until the hospital is can receive patients, should be planned for. A casualty assembly point (assembly point for the injured) can be designed to meet this need. Alternative transport routes should also be identified in advance.

If a hospital lies within the accident area, it is important to shut doors and windows immediately and also to be able to shut off ventilation systems immediately. These considerations should be included in the local emergency preparedness planning of hospitals and other treatment facilities. In cases where a drifting gas cloud has passed, the premises should be aired before the ventilation system is restarted.

Where experience is limited or lacking, it is important to plan for taking samples at the most critical stage of accident response for later analysis (blood, urine, head space samples in case of exposure to solvents). If not planned for in advance, sample-taking may be forgotten. How it is to be carried out should be decided on a case-by-case basis. Initially, it is advisable to take two 10 ml. blood samples in heparin tubes. One of these should be centrifuged and the plasma separated. The plasma and the tube of whole blood should be frozen. Urine samples should also be taken, one portion of the diurnal urine being kept and frozen.

Decontamination stations should be located at every hospital or other treatment facility where patients exposed to chemicals might be admitted. A decontamination station should in most cases be connected with the emergency unit -- for example, at the ambulance entrance or in a special room with separate ventilation and, if possible, with an air lock. It should also be possible to sluice recumbent patients. Clothing is removed before or during sluicing and placed in, for example, plastic bags. Plenty of warm water is needed for this purpose.

For decontamination at a hospital, the staff should be equipped with protective equipment. The responsibility for setting up decontamination stations at hospitals and other treatment facilities should be allocated (probably to the relevant medical care authority).

3.4 Protection of rescue workers and medical personnel

Medical personnel should, in principle, never enter a contaminated area (see Section 2.4). They should only work at casualty assembly points to which the injured are brought after decontamination. They may need to assist in decontamination, but in this case they should be equipped with a full mask in case there is a change in wind direction that would expose them to a toxic chemical. Rubber gloves, a simple apron or protective coat (and hood), and rubber boots should also be available.

Only exceptionally should medical personnel enter the accident area, for example to carry out triage or to give life-saving treatment. They should in this case wear full protective equipment all the time. As a rule, they should be guided by rescue personnel who have been trained to work in this environment.

Medical personnel may also need protective equipment at hospitals or other treatment facilities, especially during the decontamination of victims.

3.5 Psychological and psychiatric reactions

Aside from direct or indirect biological effects of toxic chemicals on the nervous system there are often psychological and psychiatric effects. This psychological and psychiatric picture is determined by indirect effects related to the perception of the accident by either individuals or *perceived* risk may cause stress reactions even if there has been no real exposure.

The general public has a tendency to consider all chemical substances as being extremely hazardous, alongside "radioactivity". Stress responses occur frequently and they may overshadow the importance of organic health effects. Experience has shown that a significant rise in stress-related psychiatric and psychosomatic symptoms may be induced when there is a major environmental threat. Such a rise in morbidity may still be demonstrable many years after such an event.

Bertazzi (1989) has suggested that industrial disasters have the following major characteristics in common:

- uncertainty about the nature, extent and future implications of the accident;
- housing and job insecurity caused by evacuation and/or fear of contamination of homes, and by a drop in orders for local products;
- social rejection of those who are thought to be "contaminated";
- media siege that might aggravate fears that the worst has happened;
- cultural pressure related to often conflicting public opinion on what to expect and how to behave (for example, in regard to whether exposed pregnant women undergo an abortion or not).

3.5.1 Determinants of stress reactions

The reactions of the public will be determined mainly by three groups of variables: (a) the characteristics of the accident itself; (b) information about the accident and the manner in which this information is disseminated; and (c) individual characteristics of those exposed to the potential threat.

3.5.1.1 Nature and extent of the problem

The important features that determine the reaction of individuals or groups of individuals include the following: (a) the scale of the problem and the substances involved; and (b) the time course of events. Some accidents have an obvious beginning or even an acute phase, as is the case in many "overt" industrial disasters. In other cases the disaster may be more "diluted", i.e. the (threat of) exposure to dangerous chemicals may exist for some time before it becomes known to the authorities and/or to the public.

3.5.1.2 Information and communications

Information about a potential health hazard may cause considerate alarm, even before it becomes clear whether any real physical harm is likely to occur. The available information and the manner in which this information is communicated may be important intermediate variables for determining subsequent psychological and psychiatric reactions.

The following aspects of the information about a risk situation may shape the reactions that ensue:

- availability of information beforehand, for example the presence of a sense of threat before an accident occurs;
- duration of the period of uncertainty and confusion that follows the accident;
- the trustworthiness of the source of information (the public often suspects that official information is coloured by political and/or economical interests);
- an understanding of the "meaning" of measured concentrations of a (toxic) chemical.

Concentrations that exceed guideline values derived for long-term occupational exposure are not necessarily toxic and may not equate with the need to take action or a likelihood of subsequent health effects, provided only a brief, non-occupational exposure is involved.

Relevant aspects of the way information is generally communicated:

- Spread of information through informal communications networks such as schools, factories, companies, etc. This information, usually spread in the early stages after an event, is often inaccurate and may cause marked stress reactions;
- After most major chemical accidents extensive media coverage follows. Such coverage can be a valuable source of information for the public. However, there is a risk that inaccurate or contradictory information may aggravate the situation.
- Another disadvantage of information spread by the mass media is that people might not pay attention to the information at the time it is given. On the other hand, people may not be able to find the information they want at the time they need it.
- Information may also be transmitted through telephone services. Such a service may be an important supplement to the mass media. It provides information at request, thereby adding to a sense of control.

3.5.1.3 Personal characteristics

Personal involvement with the calamity (severity of personal injury or loss, amount of forewarning received, opportunity to control or escape) is obviously one of the most important factors determining psychological response. Rescue workers and their direct helpers may be prone to moderate or severe stress responses. Vulnerability to stress may differ according to a number of personal characteristics:

- Mothers with children are usually among those most concerned. They are also at greater risk for showing pathological reactions.

- Pre-existing mental health problems, which are present in 15 to 20 per cent of the average population, are other important risk factors.

- Male sex, high level of education, coping skills and, especially, preparedness for a disaster through training or experience appear to be protective factors.

3.5.2 Characteristics of stress responses

Depending on the type of accident concerned, stress responses with specific features may be present:

- Acute reactions: in some people, maladaptive behaviour such as immobilizing fright, emotional breakdown, uncontrolled fright or irresponsible heroic behaviour patterns occurs Another type of reaction in the acute phase, which occurs more commonly, is emotional stunning. It usually leaves goal-directed behaviour more or less intact. This reaction may last from hours to days after the accident.

- Intermediate reactions: In the first weeks to months after a serious traumatic event, symptoms of post-traumatic stress are common. These include: intrusive memories of the event (for example, nightmares), sleeping problems, irritability and heightened startle response, depressed or anxious mood, and feelings of guilt.

- Late and chronic reactions: Independently of whether symptoms have been present in the acute phase, a chronic stress syndrome may emerge, sometimes not until years after an event. Such a chronic syndrome is especially likely to occur in cases where exposure to chemicals involves a long-term threat to health, for example after exposure to dioxins. This syndrome has several features in common with the post-traumatic syndrome described above. Non-specific somatic complaints, often related to hyperactivity of the adrenergic system, may be more prominent, as may be hostility and distrust. Such chronic reactions may be complicated, and may be sustained by the fact that victims are often met with social rejection because they are considered to be "contaminated".

3.5.3 Recommendations for psychological and psychiatric measures

Preparation for emergency responses should include the identification of groups at risk for stress reactions, an assessment of information available to the public, and an assessment of networks through which information is likely to pass. In high-risk areas, epidemiological data and internationally accepted instruments for the assessment of mental health impact should be available so that immediate monitoring activities can take place. Plans should be ready for informing the public throughout the different stages following an emergency. Detailed plans should be available in high-risk areas for the construction of an information network that can be put in place as soon as it is needed. A telephone service for the public should be established, as well as a strategy for communications through the mass media in order to channel the proper information.

Emergency teams who deal with the aftermath of an accident involving the risk of exposure to toxic chemicals should preferably include a psychiatrist or psychologist. This individual should perform the following tasks, amongst others:

- provision of emotional support for rescue workers;
- close collaboration with information services;
- assistance in screening activities for mental health problems in risk groups;
- assistance in setting up a network for treatment of cases of stress syndromes. In most cases treatment should be organised through existing mental health facilities.

3.6 Accident follow-up

Short-term and long term follow-up of victims exposed to toxic chemicals may be of importance both from the therapeutic and scientific point of view. For this reason, proper registration of *all* persons exposed, regardless of whether or not they have or have had symptoms, is of vital importance.

The onset of symptoms following exposure to chemicals may be delayed for hours or even days. It may be necessary to seek out these individuals in different ways so that adequate observation and where necessary adequate treatment can be given.

From the scientific point of view, short-term and long-term follow-up of those exposed to chemicals and evaluation of the accident are essential. For many chemicals, little or no information is available regarding their effects on human health. Any experience it is possible to obtain is therefore of the utmost importance. Even in the case of exposure of small groups, it is important to gather and evaluate data so that they may be used in epidemiological studies in the future.

3.6.1 Initial activities

Samples for biological monitoring of exposed individuals or groups of individuals should be taken immediately, or as soon as possible during the first response. In the case of chronic or intermittent exposure, it is advisable to take biological samples during or immediately after exposure has ended. If the initial samples are not taken, it may be impossible to assess later whether individuals were exposed or not, which then makes follow-up and epidemiological studies difficult if not impossible. The importance of active fact-finding during the initial stage has therefore to be stressed.

Environmental samples form the basis for assessment of the exposure when it is not possible to take biological samples from all exposed humans. Sampling of the environment (water, food, air, soil) is needed to study the sources and routes of exposure. The history of environmental pollution -- the time sequence of events -- can provide useful information for the decision-making process, especially to determine how long the population has been exposed to the agent.

Epidemiological studies should be planned carefully, as they are often time-consuming and expensive. Decisions made in the initial phase will determine the future follow-up. These decisions may be made based on limited information, which may make planning difficult. The exposed group and the comparison groups for epidemiological studies should be selected so that the contrast with the exposure time is maximised.

3.6.2 Post-disaster follow-up

In the case of intermittent exposure, environmental monitoring can be extremely helpful. The history and time sequence of pollution can be explored, for example by sediment analysis of lakes or rivers for surface water pollution. This provides a good basis for historical exposure assessment.

Animals can be used as a sentinel for environmental disasters. For instance, in the Minimata disasters cats developed "cat dancing disease" before humans became ill. Biological monitoring of animals can be carried out by veterinarians.

Casualties can be followed, based on information from hospital admission records. It is more difficult to follow those who have been exposed but do not have symptoms. In the case of agents causing long-term effects (for example, cancer), follow-up should be organised and relevant population groups should be established for comparison with those exposed, in order to be able to study the incidence of outcome in relation to the exposure. The follow-up should be stopped at a stage where the cost/benefit ratio of the follow-up becomes unacceptable.

Follow-up is expensive, but in the long run it can be cheap compared to ignorance. Without adequate follow-up, one can find oneself in a hopeless situation of frustrating attempts to investigate the effect of an accident on human health without any relevant data. Funding mechanisms for accident studies are lacking in most countries, and much relevant data for follow-up have therefore been lost.

National and local governments, and industry associations and companies, need to be aware of the great importance of follow-up studies and of the need to start collection of information and samples from the outset, in the event of an accident occurring. This will require not only financial but also organizational resources, for example making technicians available. Follow-up accordingly needs to be provided for at the planning stage. Funding agencies should be encouraged to regard follow-up studies in poorer countries as projects that deserve support.

4. TRAINING AND EDUCATION FOR CHEMICAL ACCIDENT PREVENTION, PREPAREDNESS AND RESPONSE

4.1 Introduction

For the health sector as well as other parties, training and education play a very important part in chemical accident preparedness and response (see also Chapter 1, "Health Sector Information and Communications Needs", and Section 2.2, "Organisation of health sector response"). National and international programmes such as UNEP's Awareness and Preparedness for Emergencies at Local Level (APELL) process provide training in the implementation of agreed joint emergency response plans.

Appropriate training and education can also play an important part in accident prevention. For example, workers who are aware of potential risks to life and health are more likely to be safety-conscious. The implications for the health sector are that it needs to consider its role, not only in training its own people (both in their professional responsibilities and in understanding the responsibilities of other professionals), but also in contributing, where appropriate, to the training of others.

4.2 Groups to be trained and educated, and parties who should take part in training and education

Training and education should be geared to the educational level of each group being trained. The following groups need various types and levels of training and education:

4.2.1 The community

People living in the vicinity of chemical installations and other workplaces where chemicals are handled have the right to know about the risks involved with chemicals. They should also be trained in how to react in emergency situations.

These people need to be told what to do in case of chemical emergencies, for example chemical spills, ruptures of large chemical containers, or sudden releases of gas or vapour. Training and education should emphasize avoidance of exposure or any type of direct contact with chemicals, through staying indoors with windows or "air intakes" (vents) closed and the mouth and nose covered by a wet towel.

In view of the variations in the educational level of the general population, it is evident that information should be presented in a simple, comprehensive and appealing way. Video presentations, illustrated booklets or flyers, and similar materials may be appropriate means of providing basic information on how to react in cases of emergencies involving chemicals. The use of the media in disseminating such information (for example, through local or regional television programmes) may be appropriate under certain circumstances.

Various parties should contribute to the preparation of educational materials for the general public, including not only members of the health care professions and volunteer organisations like the Red Cross, but also public authorities and civil defence and rescue services.

The responsibility for ensuring that appropriate information is being provided to the public lies with the local, state/regional, or national public authorities. However, where public authorities are not able to fulfil this responsibility completely due to, for example, resource limitations, they should be able to rely on industry (including major chemical users) to participate in this training and education. The division of responsibility between the public authorities and industry in this regard should be clearly defined.

Industry could prepare information in advance for dissemination in the potentially affected area in the event of an accident. This information ought to include what people can do on their own, and how they should behave during an emergency. Moreover, local installations where people from the potentially affected area work can provide this type of information in advance of any potential accident. This can also be done when the concentrations of toxic substances are just over threshold levels, without there being a need for direct action. In such a case, explanations need to be supplied concerning the meaning of threshold levels and, occasionally, of preventive measures.

4.2.2 Workers

Workers have the right to be educated regarding the potential hazards of chemicals, as well as regarding appropriate preventive measures. In addition to information on how to avoid different types of chemical emergencies, they should be supplied with information on how to react in emergency situations

The training and education of workers should be provided on different levels and through various means. Upon employment, workers in chemical installations and other workplaces where chemicals are handled should be given extensive initial training highlighting the types of chemical hazards involved, the consequences of exposure, how to avoid dangerous levels of exposure, and the actions to be taken by individual workers and their supervisors in emergencies. Such training should be well-organised and presented in an interesting manner, making use of different means including lectures and video presentations. Such training should not be a one-time-only event; refresher courses should be given at regular intervals.

Worker training should also include practical exercises under conditions of simulated chemical accidents. In addition, simple charts showing clearly the major preventive measures and the steps to be taken by the workers in the event of chemical accidents (and other types of acute exposure) should be made available and placed in such a way as to draw workers' attention.

Provision of training to workers is the responsibility of the employer.

At facilities where they exist, occupational health and safety (OHS) specialists have an important role to play. Health care professionals should be prepared to advise and assist these specialists, where they exist, and otherwise to advise industry management on how to incorporate health information into the safety training of workers.

4.2.3 First responders

First responders (such as the police, fire and ambulance services, and in some areas the coast guard) should at a minimum be made familiar with: the characteristics of different types of chemical accidents; protective measures, including the use of protective clothing and equipment; contamination hazards; decontamination indications and procedures; specific first aid measures; and the potential psychological/psychiatric effects of major chemical accidents on victims and on those taking part in emergency response.

Detailed information should be provided concerning: the chain of command at the accident site; how the various organisations and authorities work together in an accident situation; and the identification, triage and initial treatment of victims (see Chapter 2).

Again, education should not be restricted to the provision of information by different means, but should include regular practical exercises at different levels covering single aspects such as first aid or decontamination procedures, as well as simulations of both small-scale and large-scale chemical accidents. Simulation training exercises should be directed towards situations involving the specific chemicals manufactured, stored or transported in the a- .

Regular in-service education should be arranged, in order to keep this information up-to-date and supply specific information on standard operating procedures in the local area.

It is the responsibility of the management of emergency response services to see that their personnel are fully trained. Members of the health care professions should, however, be prepared to advise and assist where necessary.

4.2.4 Medical staff and other health care professionals

Concepts of mass casualty management and specific information on chemical emergencies should be part of the training of physicians, nurses and paramedics from the earliest stages, covering both theory and practice (see Chapter 2). Health care professionals should be made familiar with: the chain of command at and during a chemical emergency; models of in-hospital command and control; the identification of decontaminated and non-decontaminated patients. the use of triage; the psychological reaction of victims, emergency responders and the public; and the methodology for diagnosing and treating a large number of potential patients.

Provision of background material for this type of training and education should consider the needs of the group of health care professionals addressed. This will require the participation of specialists from different medical sub-disciplines. Specialists from Poisons Information Centres, chemical response centres and other emergency centres should be involved.

Regular in-service education should be arranged by health authorities in order to keep this knowledge up-to-date and supply specific information on standard operating procedures in local areas.

Staff at Poisons Information Centres, chemical response centres and other emergency centres should receive regular updating of information and should ensure that they receive this updating by whatever means are appropriate (see Section 1.2.4). Industry and public authorities should provide assistance in this regard.

4.3 Joint training and exercises

In addition to the training and education of the aforementioned groups, it is very important that all those with specific responsibilities in chemical emergency response should receive joint theoretical and practical training in the use and implementation of jointly agreed emergency response plans. This will enable them to practise their skills, and to become familiar with taking part in a broad co-operative effort to respond to a chemical accident.

Training should include communications exercises, small-scale (hospital and emergency service) response exercises, and full-scale simulations involving industry, health care professionals, emergency services, and others with responsibilities in this area such as civil defence and military authorities.

The medical aspects of on-site as well as off-site emergency response plans should be tested under simulated conditions. Unannounced tests of the total plan or relevant parts of the plan should be carried out, even under adverse conditions. Attention should be given to specific elements of the plan, such as: the availability of equipment; the availability of needed information; and the availability of communications between, and the co-ordination of, various parties.

Following each exercise, a full evaluation and critique should be made and the findings circulated to all the parties concerned.

Training in the implementation of plans should be scheduled regularly in order to allow well-trained response teams to maintain their effectiveness at all times.

The trainers themselves need to be properly trained and kept current. Video presentations, films and other audiovisual aids, and case studies/accident analysis reports could be used to make training more effective. Lessons learned from the evaluation of exercises, and from the investigation of actual accidents or near-misses, should also be included.

Public authorities at all levels could provide training and course materials, including audiovisual materials, to trainers in order to facilitate their work.

Industry should take a leading role in implementing joint training and exercises, and could provide resources for these activities.