
**MEDICAL RESPONSE TO
CHEMICAL EMERGENCIES**
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INTRODUCTION

The widespread production, storage, transport, and use of chemical products, which reflects the technological progress of societies, entails the potential risk of accidents involving hazardous substances at almost any moment.

The chemicals industry in our Region has developed rapidly, making it one of the major factors in economic development for many countries. However, the organization of programs for prevention, preparedness, and response to the emergencies brought on by chemical accidents, including preparation of the health sector for dealing with the aftermath of events of this nature, has not developed at the same pace.

If the special characteristics of chemical accidents that differentiate them from other kinds of disasters are taken into account—including the high risk potential of secondary contamination, the toxic effects on large numbers of people of massive chemical poisoning, the immediate or eventual development of the toxic process in the affected populations, and the wide diversity in the degree and dynamics of the clinical manifestations of chemical intoxication—it will be seen that the medical response to these kinds of accidents must also have special characteristics. This is the essential aim of this presentation, which will address some of these factors, including the areas into which the response of the health sector may be broken down—for example, the necessary medical equipment and the drugs and antidotes required for the emergency kits to treat cases of chemical poisoning.

I. GENERAL BACKGROUND INFORMATION

The term **chemical accident or emergency** is used to refer to an event or circumstance that results in the uncontrolled emission of one or more substances hazardous to human health and/or the environment, incurring high economic costs. Such events come about in many ways, most frequently as the result of:

- Fire or explosion in an installation where potentially toxic substances are handled or manufactured.
- Accidents in warehouses that contain large quantities of assorted chemical products.
- Accidents during the transport of chemicals.
- Misuse of products that lead to the contamination of food, water, the environment, etc.
- Improper waste management, such as uncontrolled disposal of toxic products, deficiencies in waste disposal systems, or accidents in wastewater treatment plants.
- As secondary effects of a natural disaster.

RISK FACTORS FOR CHEMICAL ACCIDENTS

The term *chemical risk* is defined as the probability of a chemical substance causing harm to an organism under specific conditions of exposure. Similarly, if we associate this risk with accidents involving hazardous substances, it refers to the probability of this kind of event occurring and also its corresponding effects on health and/or the environment.

Several factors contribute to the occurrence of chemical emergencies and their impact on public health. These factors have to do with the chemical substances involved as well as with the people or

environments affected. For an accident involving hazardous substances to occur, the materials must be in a state that will permit them to be released, to explode, or to catch fire. Natural phenomena such as earthquakes can cause a chemical emission, but it is usually human error, equipment failures, or hazardous conditions that set off the event, whose consequences will depend on the characteristics of the substance or substances involved, namely their acute and long-term toxicity, corrosiveness, flammability, volatility, and the quantities involved.

For chemical emissions to have an impact on public health, the victims involved must be exposed to the chemicals, to the fire, or to the effects of an explosion. The workers on the scene of an accident are usually at greatest risk from the start. The first to arrive on the scene in response to such an accident, e.g., firemen, policemen, or other rescue personnel, may also be at risk if they are not adequately protected. A high-risk group that is frequently forgotten are the health workers, who may be exposed at a distance from the place of the emission if the victims directly affected have not been properly decontaminated before being transported to medical facilities. Communities far from the site of the accident may also be affected indirectly by the contamination of water and food.

The distance of the residents of a community from the emission, the prevailing climatic conditions, the vegetation, the sources of drinking water, and other conditions in the area of the accident are frequently critical determinants of the effects of such accidents on human health and the environment.

CONSEQUENCES OF CHEMICAL ACCIDENTS

While it is true that the consequences of chemical accidents are dependent on the factors mentioned above, they are also dependent on the effectiveness of the measures taken to reduce these consequences insofar as possible, essentially as they concern health, the environment, and property.

Effects on Health

The effects on health of accidents involving chemicals may be the result of direct or indirect exposure to hazardous substances or the results of their degradation.

Possible Effects

- **Acute effects**, which may either be **local** (if the damage occurs at the site of the contact of the chemical substance with the human body, usually the skin, eyes, mouth, respiratory tract—for example, the irritation produced by the inhalation of ammonia vapors or the injuries to skin and mucous membranes produced by acids and alkalies—or **systemic**, once the substance is absorbed and distributed throughout the organism and the damage becomes apparent in a place far from the site of penetration—for example, depression of the central nervous system produced by volatile hydrocarbons or peripheral neuropathy produced by metals. Acute effects vary broadly depending on the type of substance involved and may affect different organs and systems, so that their clinical manifestations may be an expression of neurological, respiratory, gastrointestinal, liver, renal, or other damage.
- **Long-term effects**, which are caused by the long-term presence of a harmful substance that contaminates the water, soil, and food, an indication that exposure to the substance is

continuous. Long-term effects include carcinogenesis, mutagenesis, teratogenesis, respiratory diseases, and chronic encephalopathies.

In addition to the effects on health that may be observed in chemical accidents through exposure to the substance involved, the following may also occur:

- traumatic injuries (multiple fractures, hemorrhages, rupture of organs, sudden death, burns) as a result of explosion and/or fire;
- the appearance of psychological reactions resulting from stress, such as depression, anxiety, and confusion.
- the appearance of communicable diseases as the result of the displacement of the potentially exposed population to areas lacking adequate services and a sufficient supply of drinking water, or with poor sanitary conditions;

Effects on the Environment

- Pollution of the abiotic environment: soil, air, surface and groundwater.
- Death of various sensitive organisms: birds, fish, and other aquatic organisms, plants, soil microorganisms, fungi, mammals.
- Contamination of food.

Economic Effects

The absence of centralized registries to monitor the costs incurred by chemical accidents make it difficult to determine the economic impact with any degree of precision. Nevertheless, it has been estimated that the aid provided to the affected populations alone in the form of drugs (including antidotes, which are very expensive), special medical equipment, transportation, food, and the repair of dwellings and other installations, funded with resources from other countries and local sources, represents all told an expenditure of thousands of millions of dollars each year.

CHARACTERISTICS OF CHEMICAL ACCIDENTS

- Accidents involving hazardous substances range from those confined to a relatively specific place up to those that spread so far as to endanger the entire community.
- All the victims of "pure" chemical accidents suffer the same kinds of harmful effects; only the magnitude of the harm differs.
- There may be a toxic zone that can only be entered by personnel wearing the appropriate protective equipment. Ambulances and other medical personnel should never enter such areas.
- Victims exposed to chemicals may constitute a risk for rescue personnel, who themselves may be contaminated by contact with them. Consequently, preliminary decontamination should be

carried out before the victims are seen by medical personnel. Furthermore, those responsible for providing such care should know how to evaluate and manage the medical disorders presented by contaminated victims and how to protect themselves from the risk of secondary contamination.

- Hospitals (and other treatment facilities) and their access routes may be included in the toxic area; access may thus be blocked, and new patients will not be able to be admitted for a considerable period of time. Accordingly, plans should provide for setting up temporary medical facilities in schools, sports centers, tents, and the like.
- General knowledge of the properties and effects of many chemical substances may not be complete, and consequently effective systems for obtaining essential information on the chemical substance or substances involved should be identified, and this information should be transmitted to rescue teams and others who require it.
- It may be necessary to perform environmental toxicology studies and/or studies of the bodily fluids of contaminated patients. It is therefore important to identify laboratories with the capability for conducting these kinds of analyses.

II. MEDICAL RESPONSE

Response to chemical accidents requires multi-institutional and multidisciplinary coordination, and the lack of such coordination may have a very negative impact or even exacerbate the effects of a given accident. The health services play an important role in response, and well-established systems exist in most of the countries of the Region that can act in the event of emergencies produced by natural disasters. In many cases, however, these systems are not prepared to deal adequately with accidents involving hazardous substances.

The medical sector may be broken down into several areas of responsibility. These include:

- Rescue of patients.
- Triage.
- Treatment and stabilization of patients.
- Transport of patients and distribution to medical facilities.
- Medical resources.

Rescue of Patients

With respect to rescue activities it is necessary to bear in mind certain considerations related to the focus of contamination:

- The term *focus of chemical contamination* is applied to the area subject to the influence, harmful effects, and contamination caused by the factors intervening in accidents involving hazardous chemical substances.
- It is very difficult to demarcate the area containing a focus of chemical contamination, since it depends on the geographical characteristics of the terrain, meteorological conditions (prevailing wind direction and speed), the nature of the buildings, the kind of population (urban and rural), the kind and quantity of chemical substances involved, their toxic properties, and the concentrations capable of causing alterations in health.
- In a focus of chemical contamination it is characteristic to find large numbers of victims that appear simultaneously over a large land area.
- The means of penetration of the toxic substances into the organism: inhalation, ingestion, skin, and mucosa.
- The toxicity of the substances involved, which may range from extremely high--producing severe intoxication with very small doses and, accordingly, requiring prompt medical care--to low toxicity.
- Patients should not be treated in the area of contamination. If the rescue of patients from this area is necessary, it should be carried out by hazardous substance operations personnel.
- The risk of secondary contamination.
- In order to prevent unnecessary exposure, all those involved in the rescue process should be considered contaminated.
- As a general rule medical personnel should not be involved in the direct control or management of hazardous substance emissions.

Triage

Triage is a process involving the assessment and classification of the conditions of exposed victims and the designation of priorities for decontamination, treatment, and transfer to health facilities.

Triage is an ongoing process and should be carried out at regular intervals, since the condition of patients may vary drastically at the various points in the chain of treatment--for example, when they receive specific therapy or are dependent on the availability of resources.

The principal aim of triage is to provide the best possible care to a large number of patients with the resources at hand. In major chemical accidents the number of patients exceeds the capacity of medical personnel to administer immediate care, and when the available resources--that is, personnel, supplies, drugs, and transportation--are plentiful, **all those affected** should be given optimal care. However, in situations where resources are insufficient, it may be necessary to defer the care of the most seriously injured, who would require extensive resources, and provide only support treatment in order to focus most of the attention on the less seriously injured who have a greater chance of survival.

Classification of the injured after exposure to chemicals follows the same principles as for any other kind of accident, and the criteria for classification by symptoms are the same as those customarily employed. There is, nonetheless, a special classification that may be termed "chemical group," for individuals exposed to certain kinds of substances and in whom symptoms may take hours to appear. Such would be the case, for example, in exposure to irritating gases, such as nitrogen oxides or to chemical products that are absorbed through the skin.

Numerous systems are employed to prioritize patients for treatment and transfer to a hospital. The most often used are color and/or numerical codes that classify the patient's condition and treatment priority. These systems are based on five levels of priority:

- Priority I:** Patients in critical condition. Treatment and immediate transportation are required.
- Priority II:** Patients with moderate and serious injuries. Emergency transportation is required but can be put off until Priority I patients have been removed.
- Priority III:** Patients with minor or no injuries. Emergency transportation is not necessary. Assessment and treatment in consultation with the hospital is sufficient.
- Priority IV:** Nonviable patients who require only support treatment and no transportation.
- Priority V:** Asymptomatic patients who are expected to develop clinical symptoms. These require observation and probably immediate treatment, in addition to transportation to a medical facility.

Proper classification of patients by priority is necessary in an emergency, since a mass transport operation would interfere with the basic activities of the hospital and with its primary purpose of providing care for seriously injured patients.

Treatment

The treatment area should be located in a place where patients and medical personnel will be safe from toxic exposure; the area should also provide easy access for transport vehicles. In accidents involving large numbers of patients the treatment area should be divided into different zones corresponding to the levels of priority established in the triage.

The initial examination of chemically contaminated patients should determine:

- Which injuries are related to toxic substances;
- What parts of the body have been most severely exposed;
- The entry route.

The treatment of patients injured in a chemical accident follows the same basic principles as the treatment of any isolated case of chemical intoxication; it will depend on the condition of the particular

patient, the type of chemical substance involved, the entry route, and the availability of resources. The basic principles for the treatment of such patients are:

NONSPECIFIC TREATMENT

Nonspecific treatment may be defined as the measures employed to:

- Maintain vital functions: This includes cardiopulmonary resuscitation, treatment of convulsions, correction of electrolyte imbalances, etc.
- Eliminate the toxic substance from the entry route and diminish absorption. These are what are known as decontamination procedures.
- Eliminate the toxic substance absorbed, known as active elimination therapy.

SPECIFIC TREATMENT

- Antidote therapy.

All clothes should be removed from contaminated patients before they enter the treatment area so as to prevent unnecessary contamination of medical personnel. The simple removal of patients' clothing reduces the potential contamination of hospital and rescue personnel by 85%. All clothes should be properly packed in safety bags.

If the condition of the patients is life threatening, cardiac and trauma support measures should be given priority over procedures to reduce contamination. If decontamination has not been completed, these procedures should be carried out with adequate protective equipment.

Lists of the equipment and antidotes most frequently employed in chemical accidents appear in the Annexes. Proper planning that includes analysis of the most frequent accidents in a given country and potential accidents, based on the inventories of hazardous installations and chemical substances, should include the preparation of emergency kits containing the necessary antidotes.

Transportation

The transportation of personnel in chemical accidents may pose a real risk for both the transport personnel and the equipment itself. Certain steps should therefore be taken to reduce this possibility to a minimum—for example, the use of protective clothing.

The vital functions of patients should be maintained during transport, taking the appropriate steps for this purpose (administration of oxygen and parenteral fluids, cardiovascular resuscitation, etc.). In some cases antidotes may be administered during transportation—for example, atropine in cases of intoxication by organophosphorus compounds.

Prior contact should be made with hospitals that are receiving injured patients so that the hospitals can prepare themselves for the emergency and, in turn, contact toxicology information centers, if available,

to obtain information on the specialized medical treatment appropriate for the kind of toxic substance involved.

The transportation officer is responsible for the distribution and transport of patients to hospital areas. This requires coordination with the medical command, the officer in charge of treatment, and the medical facilities receiving the patients. Accidents involving hazardous substances can rapidly overwhelm the capabilities of medical treatment sites, and therefore the transportation officer should carefully monitor the status of the medical facilities and their ability to accept patients.

Given the potential for contaminating the means of transportation and the personnel providing it, adequate protection must be maintained in this activity.

Medical Resources

One of the most important activities in planning the response to chemical accidents is projecting the medical resources that will be needed to care for victims. Lists of antidotes, drugs, and necessary equipment appear in the Annexes.

Conclusions

The success of the response to chemical accidents and the minimization of their consequences depend totally on the organization of the entire enterprise. For this reason the flow of communication between the medical command and the accident command is a matter of vital concern, as is the planning of the medical response.

Table 1. List of Antidotes

Antidote	Principal Indication	Other Possible Indications
Amyl Nitrite [*]	Cyanide (A2)	
Atropine ^{* #}	Cholinergic syndrome (A1)	
Calcium Gluconate or other soluble calcium salts	Hydrofluoric Acid, Fluorides, Oxalates (A1)	Calcium antagonists (B3)
Diazepam [*]	Organophosphorus compounds (A2)	Chloroquine (A2)
Dicobalt Edetate [*]	Cyanide (A1)	
Dimercaprol ^{* #}	Arsenic (B3)	Gold (C3), Inorganic Mercury (C3)
Hydroxocobalaminum [*]	Cyanide (A1)	
Methylthionine Chloride (Methylene Blue) [*]	Methemoglobinemia (A1)	
Obidoxime [*]	Organophosphorus insecticides (B2)	
Oxygen [*]	Cyanide, Carbon Monoxide, Hydrogen Sulfide (A1)	
Hyperbaric Oxygen	Carbon Monoxide (C2)	Cyanide, Hydrogen Sulfide, Carbon Tetrachloride
Ferrocyanide/Potassium Ferrate (Prussian Blue) C177520 [*]	Thallium (B2)	
Pralidoxime [*]	Organophosphorus insecticides (B2)	
Sodium Nitrite ^{* #}	Cyanide (A1)	
Sodium Thiosulfate ^{* #}	Cyanide (A1)	Bromates, Chlorates, Iodine
Succimer (DMSA)	Antimony, Arsenic, Bismuth, Cadmium, Cobalt, Copper, Gold, Lead, Mercury (organic and inorganic) (B2)	Mercury (elemental), Platinum, Silver (C3)
Unithiol (DMPS) Dimercaptopropanosulfonate	Cobalt, Gold, Lead, Mercury (inorganic), Nickel (C2)	Cadmium, Mercury (organic) (C3)

^{*} Listed in the Model List of Essential Drugs of WHO (1992)

[#] Evaluated or in the process of evaluation by experts

^{*} Available only in France

Source: Regional Course on Planning for, Prevention of, and Response to Chemical Accidents in Latin America and the Caribbean. Mexico 1993.

Table 2. Basic Medical Equipment Required for Emergency Treatment of Patients Injured in Chemical Accidents

* Maintenance of respiratory function: Oxygen Laryngoscopes Oral and nasotracheal catheters Ventilation system Ventilation mask Tracheostomy equipment Portable mechanical ventilator
* Maintenance of cardiocirculatory function Cardiac monitor Defibrillator Electrocardiograph External pacemaker
* Specific treatment of symptoms: Drugs Fluids and electrolytes Selected antidotes
* Decontamination Portable lavage equipment Ocular lavage material Gastric lavage material Lavage solutions
* Another necessary supplies: Containers for chemical samples Material for biological specimens Catheters Dressings Plastic bags Cleaning supplies Personal protection equipment

Source: Regional Course on Planning for, Prevention of, and Response to Chemical Accidents in Latin America and the Caribbean. Mexico 1993.

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ANNEX II
Agenda of the Symposium

AGENDA OF THE SYMPOSIUM

Wednesday, October 30

08:00 - 09:00	Registration
09:00 - 09:40	Inauguration
09:40 - 14:00	Simulation of an accident with hazardous material.
14:00 - 15:30	Recess
15:30 - 16:30	Open discussion
16:30 - 17:00	Policies and strategies of the PAHO Program for Emergency Preparedness and Disaster Relief (PED). <i>Hugo Prado</i>
17:00 - 17:30	Chemical emergencies within the framework of the IPCS Americas. <i>Luiz A. Galvao</i>

Thursday, October 31

09:00 - 10:15	Organization and responsibilities in the prevention and emergency planning involving chemical substances. <i>Duncan Ellison</i>
10:15 - 10:45	Chemical emergency preparedness. Mexico's experience. <i>Arturo Vilchis Esquivel</i>
10:45 - 11:00	Open discussion
11:00 - 11:15	Recess
11:15 - 11:45	Mexico's experience in accident prevention.
11:45 - 12:15	Puerto Rico's experience in accident prevention. <i>Santos Rohena</i>
12:15 - 12:45	Open discussion
12:45 - 14:15	Recess
14:15 - 15:15	Theoretical aspects on emergency planning in the site of an accident. Surveillance of the site. <i>Rodolfo Arias Díaz</i>
15:15 - 15:30	Open discussion

15:30 - 15:45	Recess
15:45 - 17:30	Preparedness for chemical disasters. Situation in Latin America. <i>PED subregional representatives</i>

Friday, November 1

09:00 - 10:30	Methodologies and support instruments in the preparation and response to chemical accidents. ▪ APELL methodology; awareness and preparation at local level: - Introduction - Preparation of response plans - Intersectoral coordination and community conscienceness - Risk communication - Experience in Mexico and other countries of the Region in the implementation of APELL. <i>Leo Heileman, Enrique Bravo</i>
10:30 - 10:45	Open discussion
10:45 - 11:00	Recess
11:00 - 11:45	Risk assessment method on chemical accidents. <i>Jesus Zagal Rodriguez</i>
11:45 - 12:30	Training, instruction, and research on chemical accidents. <i>Georgina Fernandez</i>
12:30 - 13:00	Information sources on chemical accidents. Basic library. <i>Diego Gonzalez</i>
13:00 - 13:15	Open discussion
13:15 - 14:45	Recess
14:45 - 15:15	Medical response to chemical emergencies. <i>Diego Gonzalez</i>
15:15 - 18:15	Design of action plan. Working group session. Presentation and discussion.
18:15 - 18:30	Closing