Attachment 8

HAZARD ASSESSMENT OF

WAREHOUSES

FOR CHEMICALS

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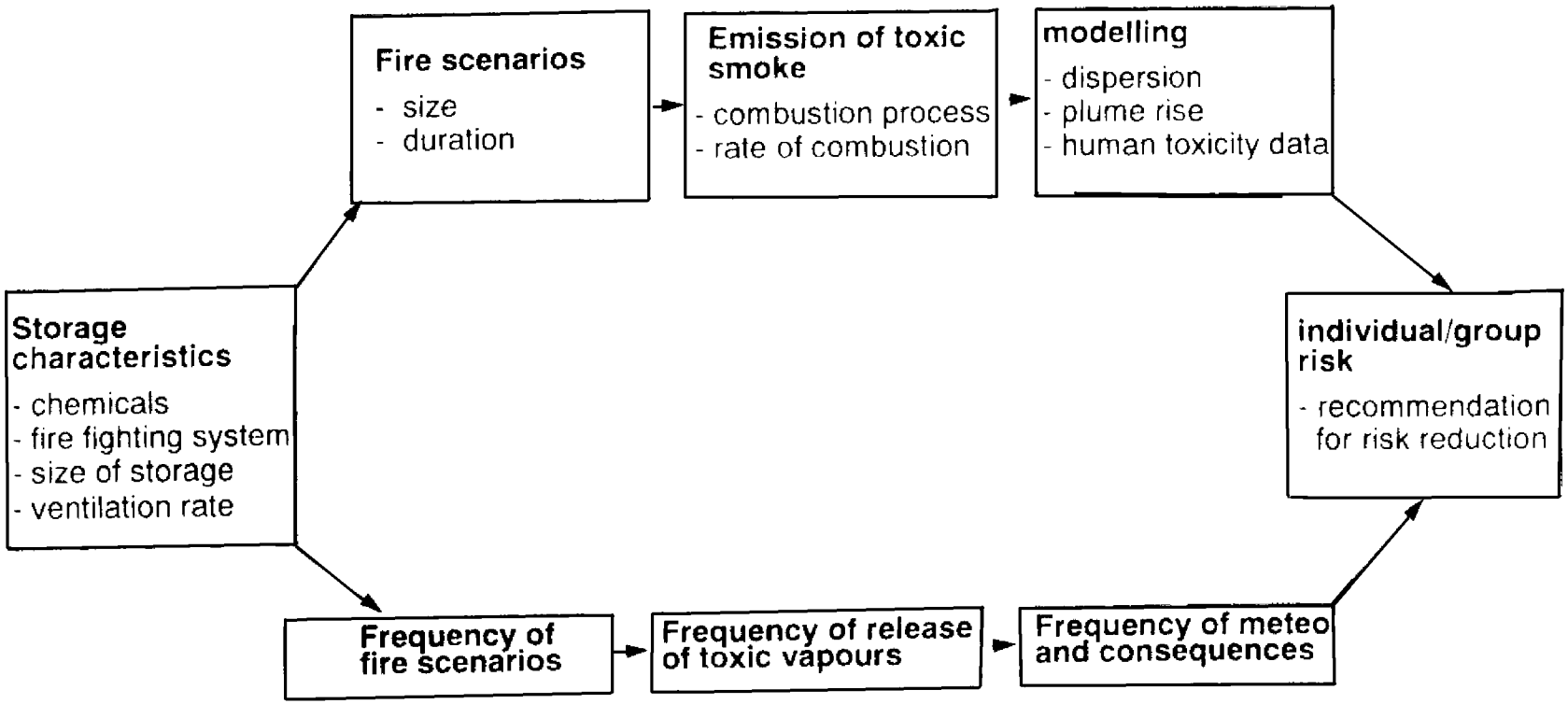

Fire scenarios
- size
- duration
Emission of toxic smoke
- combustion process
- rate of combustion
modelling
- dispersion
- plume rise
- human toxicity data
Storage characteristics
- chemicals
- fire fighting system
- size of storage
- ventilation rate
individual/group risk
- recommendation for risk reduction
Frequency of fire scenarios
Frequency of release of toxic vapours
Frequency of meteo and consequences

Fire scenarios

- Fire duration
  - all fire fighting systems ≥ 30 minutes
    exception: gas extinguishing → 5 minutes

- Fire area [m^2]
  - fire fighting system

- Fire frequency
  - warehouse 10^{-3}/year
  - probability of fire area

Probabilities

Fire fighting system	Fire area [m^2]			
	20	50	100	300
– automatic sprinkler	0.45	0.44	0.1	0.01
– gas extinguishing system	0.99	-	-	0.01
– on site fire brigade				
deluge	0.35	0.45	0.1	0.1
dry system	0	0.40	0.1	0.5
attack by fire brigade	0	0.25	0.25	0.5
– off site fire brigade	0	0	0	1.0
no extinguishing system				

Burning Rate [kg/sec]

Hypotheses:

1 complete combustion

2 oxygen availability controls mass burning rate
  – maximum mass burning rate: 0.025 $kg/m^2.sec$

3 all stored materials and packaging materials (boxes, pallets) have the same mass burning rate

Oxygen availability

$$mO_2 = \frac{0.2\,(1 + 0.5F)\,V}{24 \times 1800} \qquad \text{[kmol/sec]}$$

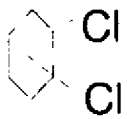
F	:	ventilation rate per hour
V	:	volume of ware house [m^3]
0.2	:	20% oxygen in the air
24	:	molar volume (m^3/kmol)
1800	:	time in seconds

Mass burning rate [kg/sec]

$$B_0 = \frac{mO_2 \times M}{c + \frac{h-(cl+f+br)}{4} + n + s + \frac{5p}{2} + mn + \frac{zn}{2} + sn}$$

$B_{max} = 0.025 \times A$

Emissions toxic combustion products

Category	Burning rate	Emission [kg/s]
All stored materials	B_0	$HCl \; \frac{cl \cdot 36.5 \cdot f \cdot 20 \cdot br \cdot 81}{M} \cdot \%act_0 \cdot B_0$ $NO_2 \; \frac{n \cdot 46}{M} \cdot \%act_0 \cdot B_0$ $SO_2 \; \frac{s \cdot 64}{M} \cdot \%act_0 \cdot B_0$
1 very toxic materials LD_{50} (oval, rat) ≤ 25 mg/kg	$B_1 = \frac{O_{2\,1}}{O_{2\,0}} \cdot B_0$	$- 0.02 \times \%act_1 \times B_1$
2 PCDD/F s 	$B_2 = \frac{O_{2\,2}}{O_{2\,0}} \cdot B_0$	$- 10^{-5} \times \%act_2 \times B_2$ TEQ

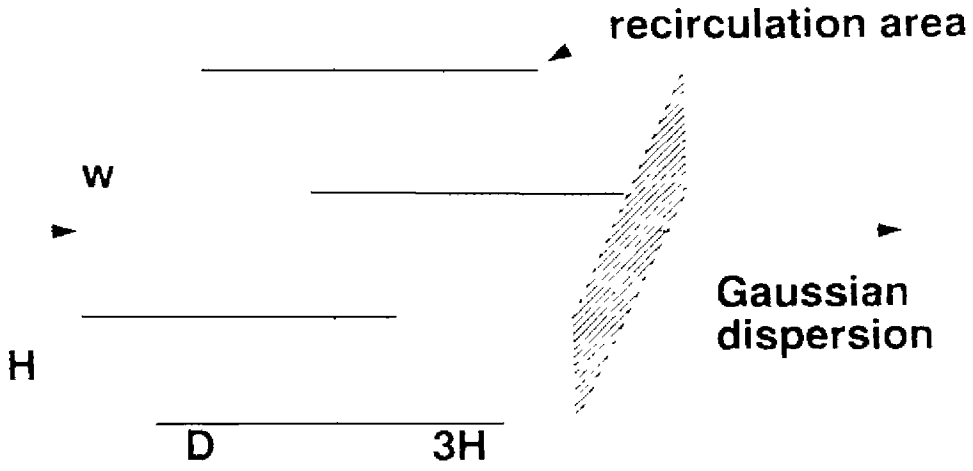
DISPERSION

Plume rise

– Generally no plume rise
  exceptions:
  - smoke relief panels
  - building not resistant

→ after 20 minutes plume rise

Wake



$w = k \times w$
wind angle 45° → k = 0.2

$$C \approx \frac{Q}{0.2 \times W \times H \times U} \approx \frac{Q}{uH^2} \quad \text{if} \quad \frac{D}{H} \approx 3 - 5$$

CONSEQUENCES

Vulnerability models

$NO_2 + SO_2 + HCl$:

$$y = -18.6 + \ln\left(\left(\left(f_{NO_2} C \right)^{3.7} + 0.549 \left(\left(f_{SO_2} C \right)^{2.4} + 1.47 \times 10^5 \left(f_{HCl} C \right) \right) \times t \right)\right)$$

y = probability of lethality (percentage)

very toxic material $y = -4.8 + \ln [C^2 t]$

LC_{01} (30 min.) = 7.8 mg/m^3

TEQ $y = 5.26 + \ln [C^2 . t]$

LC_{01} (30 min.) = 0.05 mg/m^3

LC_{50} (30 min.) = 0.16 mg/m^3

INTRODUCTION TO THE MEDICAL MANAGEMENT OF CHEMICAL DISASTERS

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1. Preamble

The word disaster derives from the Latin word astrum, or star, used on the basis of the feeling that a calamity visited upon mankind must have been due to a misalignment of the stars. (1)

A disaster is characterized not only by the extent and severity of the incident but above all by the disproportion between immediate needs and actual means available. This disproportion can be due both to a quantitative or a qualitative shortage of resources both in manpower and equipment.

A major accident with a considerable number of casualties imposes a different medical approach both due to the immediate effects of the disaster on the community and especially on the health care system and to the limited output of medical teams

Disaster medicine can be defined as this kind of medicine which will manage the disproportion between the immediate health needs and the actual available resources in the entire chain of health care.

Management includes at least three notions :

- first a notion of leadership or in other words "command, control or coordination and communication" ;
- second a notion of output and in particular the treatment capacity of the casualties and
- third a notion of fixing priorities or in the case of disasters the notion of triage with different deontological principles from those applying in normal conditions in order to save the highest possible number of casualties.

The management of the medical effects of a disaster is one of the most difficult tasks which must be performed by medical personnel. It requires a special knowledge, a professional skill in order to provide medical care of high quality in a primitive or hostile environment, and an ability in solving unexpected problems, in innovating and organizing an emergency medical system in a situation of disaster. The medical personnel is often the weakest link in the chain of rescue operations not owing to their medical technical skills but owing to a lack of competence in management and leadership. Education and training in disaster medicine are therefore essential.

Disaster medicine acquires its professional contents from many branches of medicine but first of all from military medicine.
Disaster medicine adopts from military medicine the operational principles of strategy, tactics and logistics. Both in peace and wartime the military physician has often a function of management instead of a function of remedial medicine. Military medicine developed the principles of triage, stabilization and conditioning in the field, of evacuation to medical facilities and of hygiene in the field. The war surgery applies simplified and standardized treatment procedures. The military physicians are used to act together with other forces in a hostile environment.

Disaster medicine takes also elements from emergency medicine mainly the readiness on a stand-by basis both on the spot as in the hospital and this for the full spectrum of somatic and psychic disorders. Disaster medicine calls on both the knowledge and technical procedures of emergency medicine.

Finally disaster medicine integrates elements of epidemiology, of preventive and occupational medicine, of toxicology, of psychology, of social and forensic medicine.

Disaster medicine has also its own aspects, it is a emergency medicine in the field, a global medicine, a mass medicine, a medicine with extramedical aspects and a doctrinal medicine.(2)

a. Emergency medicine in the field

It differs from medical care in the hospitals because the casualties are first cared on the spot of the disaster or in temporary health facilities very near to the scene of the disaster.
This can only happen by an adjustment of the medical techniques and by an adjustment of the behaviour of the medical teams who must learn to work in insecure circumstances without the comfort of the hospital.
In a disaster situation sophisticated techniques must be replaced by simple, standardized, effective and rapidly performed procedures. The medico-technical procedures must be rethought according to the technical set foreseen and present on the scene of the disaster, according to the environment and the duration of the relief operations and according to intervening personnel and logistic support.
Also the behaviour of the medical personnel must be adapted since they must take unusual decisions such as the organization of an emergency medical system on the scene, management and triage of mass casualties instead of the routine care of patients.

b. Global medicine

Disaster medicine is a global medicine with integration of all aspects of medical, surgical and psychological care. It calls on various specialists, each of them in his own level of qualification. (emergency physicians, anaesthesists, surgeons, internists, intensive care physicians, psychiatrists, psychologists, general practitioner, nursing personnel, paramedics, emergency medical technicians, volunteers and lay people).
A pluridisciplinarity but also a complementarity which necessitates a coordination of all medical and paramedical personnel

c. Mass medicine

Disaster medicine is a mass medicine ; it must take into account the number of casualties and the variety of injuries necessitating a triage of the casualties. The principle of triage requires that the physicians acts no longer according to the usual ethical code ; the normal and desirable tendency to devote one self fully to the saving of an isolated, sometimes desperate patient, must yield to the notion of output taking into account the number of casualties and the available resources, to select those casualties who have the best chances of recovery requiring a minimum amount of time and a minimum of resources.

d. Medicine with extra medical aspects

Disaster medicine is a medicine with extra medical aspects which can be as different as the protection against evolutive hazards, the management of the means of transport and communication, the setting-up of temporary medical facilities, electricity and water supply and so on. This needs integration and coordination with the other relief and rescue parties.

e. Doctrinal medicine

Disaster medicine is a doctrinal medicine, since it is carried out from pre-established plans including the operational strategy and the various interveners.
Disaster medicine depends on an unity of doctrine and command with a permanent balance between individual initiative and the relative rigidity of a medical plan of action. The purpose of disaster management is to return as soon as possible to the normal emergency medical system.

Disaster medicine is a medicine where all aspects of a medical strategy will appear for the benefit of operational tactics supported by logistics without fail.
A medicine where the operational tactics and the logistic aspects certainly play as an important part as the medical procedures itself

2 Effects of disasters

Both material and human effects of disasters can have repercussions on general health care of a community.

Material damage such as destruction of houses, administrative and socio-economic buildings, civil engineering structures for collective use, and industrial plants can result in disorganization or general collapse of the society with problems of housing, food and water, medical care, communication and so on.

In general a disaster will produce two categories of victims : the injured or sick casualties and the "involved" victims.
Surgical casualties will have mechanical trauma, blast injuries, thermal or chemical burns.
Medical patients will primarily have toxic inhalation causing pulmonary damage, systemic toxicity from an absorbed toxic chemical or radiation injuries.
Once information has been obtained about the exact nature of the hazard or threat, one can begin to predict the type of casualties to be expected. For example a building collaps will produce casualties with above all mechanical trauma and crush injuries, a airplane crash casualties with mechanical trauma, thermal burns and inhalation injuries, a hazardous material accident casualties with chemical burns, inhalation injuries and systemic toxicity.

"Involved" victims are casualties without injuries or illnesses but they represent this part of the population that is materially or emotionally affected by the disaster. These casualties can develop psychological problems. Some of these will require acute, intensive psychiatric intervention.

Disasters can have various effects on the public health of a community :

- a large number of casualties with a possibility of a great variety of injuries and illnesses ;
- psychological effects on the casualties and the population;
- involvement of the medical facilities. Because a hospital is part of the community, it is always possible that the hospital itself will be physically involved in a natural or man made disaster. A fire or explosion in a hospital or a ruptured rail tank of chlorine gas near a hospital would have obvious dire consequences.

Even if a hospital is not physically involved, a disaster can affect its ability to function in a variety of ways, for example, loss of physicians, nurses, and hospital personnel due to their inability to reach the hospital or their own involvement in the disaster ; loss of telephones, power and water, and interrupted delivery of supplies ;
- problems of shelter and hygiene such as environmental sanitation, food sanitation, vector control, personal hygiene, burial of dead, epidemiological surveillance of communicable diseases, vaccination, ... ;
- problems in supplying : food, water, clothes, drugs, medical supplies and equipment ;
- ecological problems.

3. Disaster Planning

The public authorities are increasingly aware that disasters are so serious that much greater emphasis will have to be given to preparedness and for preventing their consequences.
An assessment of the existing hazards such as road and rail transport, inland navigation, pipe-lines, storage and process-plants of hazardous materials is necessary with determination of damage according to categories of noxious products : inflammable liquids and gases, explosive products, toxic fluids, gases and solid products and toxic combustion products. Lethality and injury areas must be determined with an estimation of potential dead and injured casualties due to radiant heat, explosion and toxic cloud.

Disaster prevention and pre-disaster planning should be an integral part of national policies and programmes.
This can include for technological disasters such as chemical disasters : safety measures, an obligation of alert, information of the population and an internal action plan.

As part of the overall disaster plan, the health sector is responsable for all aspects of health care, including psychosocial and environmental health aspects.
The disaster planning must be based on the primary health care system and in particular on the emergency health care and the emergency medical services system for prehospital care.
The health elements of a disaster preparedness plan should be agreed by all concerned.

Disaster preparedness as related to health has three objectives which are to :

- prevent, reduce and mitigate the effects of disasters on the health of populations ;
- to protect or re-establish health services and facilities ;
- and to ensure the prompt restoration of health conditions prevailing before the disaster and, whenever possible, bring about an improvement in these conditions

The basic elements of disaster planning are :

a. Epidemiology

Studies of previous disasters will ensure preplanning based on experience. Tools particularly necessary are data bases on community profiles, hazard mapping, assessment of available resources and needs and an evaluation methodology.

Better epidemiologic knowledge of the causes of death and types of injuries and illnesses caused by disasters is clearly essential to determine appropriate relief supplies, equipment and personnel needed to respond effectively to such situations.

Emergency health decisions are often based on insufficient, nonexisting or even false information, resulting in inappropriate, insufficient or unnecessary health aid, waste of health resources and counter-effective health measures.

It is very important to know what types of disasters are most prevalent in the area because different disasters are characterized by very different morbidity and mortality patterns, and therefore, health care requirements.

Specific medical and health problems tend to occur at different points in time following the disaster impact. Severe injuries for example require immediate trauma care mainly at the time and place of impact ; while the risk of increased disease transmission takes a longer time to develop, with the greatest danger occurring where there is crowding and poor sanitation.

Effective medical response depends on anticipating these different medical and health problems before they arise and delivering the appropriate interventions at the precise times and points where they are needed most.

b. The role of the community

The community must participate in disaster preparedness by promulgating legislative and preventive measures, by maintaining law and order, by developing on alert system, by educating and training the professional services, the volunteers and the population in the basic life-saving procedures.

c. The role of the health sector

The management of mass casualties requires advance planning It includes :

- a system of needs assessment of the primary health care sector ;
- a medical alert system .
- the organisation of health care at the scene of the disaster including triage, stabilization, conditioning, regulation and evacuation (prehospital care with well-trained mobile medical teams on a stand-by basis) ;
- the education and training of medical and paramedical personnel ;
- the means of transport, both to reach the disaster area and to evacuate the victims, as well as means of communications ;
- hospital planning, including a network of mutually supporting hospitals ;
- psychological care for casualties and rescuers ;
- social aid for the population ;
- environmental and preventive health care.

d. Education

The target population for education in a disaster refers to the whole population : the public, the politicians and policy makers, the health sector and other technical services. The media must be adequately briefed and be included in education programmes.

e. Training

This should be based on the community and apply itself to all health aspects and include all sectors involved.
Simulation exercises can be repeated to ensure optimum functioning under the severe stress of an actual event.

f. Information

Information is required for advance planning of measures for prevention and mitigation of effects, for preparation and coordination of rescue, relief and rehabilitation and for evaluation after the disaster to improve preparedness for future disasters.

4. Organization of medical assistance

The community expects, in case of disaster, that an effective relief will start An efficient response of the emergency health care system must be rapid by means of a fast alert and a readiness of the various rescue services, must be adapted to the disaster and the medical assistance must be consistent and coordinated.

The aim of the emergency medical assistance in disaster situations is to provide as rapid as possible the greatest benefit for the largest number of casualties in order to achieve a critical reduction in mortality, morbidity and indirect effects within the affected population.
The doctrine of the medical disaster plan is the medicalization of the rescue and relief operations
This is only possible if an optimal preparation (medical strategy or medical preparedness plan) is anticipated together with an effective execution (medical tactics and logistics and adjusted medical procedures or a medical action plan) in order to return as soon as possible to a routine health care situation.

Medical strategy is the conception and elaboration of a medical disaster plan according to a doctrine i.e. the medicalization of the rescue and relief operations.
The analysis of the various hazards must take into account all factors which can influence an effective response such as circumstances, location and environment of the disaster, the effects on population and the environmental disruptions, and also a potential evolutive risk.

This analysis will lead to define tasks, functions and responsibilities but also a coordination system and a communication network and both the quantitative and qualitative needs (medical preparedness plan). The frequency of simulation exercises and the evaluation methodology must also be included in the preparedness plan.

Medical tactics consist of the mobilization, the distribution and the deployment of the resources in the field according to the nature of the intervention, the circumstances and the effects of the disaster and the nature of means in manpower, supplies and equipment. It requires also adjusted medical treatment procedures.

Medical logistics are the art of supplying which allow medical personnel to execute their tasks. They include various functions such as resupplying, conveying and distribution of drugs, medical supplies and equipment, relief of medical and paramedical personnel and repairing equipment. This is only possible if the medical logistics are initially anticipated in the conception of the disaster plan.

Medical tactics and logistics will constitute a medical action plan.

The medical disaster plan must be comprehensive in order to be executed in all mass casualty situations, but also specific for particular disasters and dynamic in order to adjust the medical assistance continually according to the evolutive nature of the disaster and the gathered informations.

An effective emergency medical assistance requires :

a. unity in doctrine in the planning of both predictable and non predictable disasters. A joint doctrine is necessary in order to allow a rapid integration of each rescuer in the chain of emergency medical assistance, each rescuer at his level of competence and in his speciality ;

b an unity in command, coordination and communication within the chain of emergency medical assistance ;

c. an unity of action within the chain of emergency medical assistance necessitating an optimal integration in the general chain of assistance ;

d. the mobilization of adapted and standardized means ;

e. a rapid intervention which is only possible if an optimal emergency medical system is functioning permanently.

The medical involvement is necessary as well in the planning as in the execution and coordination but also in the evaluation of the disaster plans. The medical action plan must be executed by competent personnel at all levels necessitating education and training.

The normal and traditional health care structures such as the hospitals remain the key in the care of disaster casualties. But in order to meet the objectives of disaster management i.e. the reduction of morbidity and mortality in the largest number of casualties, medical assistance and care must be started on the scene of the disaster. Keeping in mind that in most disasters involving injuries, prehospital care usually will not be definitive treatment, there are some circumstances in which well-executed prehospital care may not only alter outcome, but also significantly decrease morbidity. Even so prehospital care can be the definitive care under special circumstances such as toxic exposures.

If indicated temporary field care facilities will be set up taking into account a possible evolutive risk in time and space and a good accessibility for the means of transport. As far as possible these temporary care structures must be anticipated in the planning especially the location of the establishment and the complete equipment.

The medical assistance and care in disasters will originate from the normal health care systems by a progressive reinforcement of the emergency medical system and by starting the hospital disaster plans.

5. Medical Preparedness Plan

Following elements are essential in the elaboration of a medical preparedness plan.

a. Structure of the emergency medical assistance :

(1) the general command and coordination structures and the command and coordination structures of the emergency medical assistance;

(2) the various operational relief services which will intervene in the emergency medical assistance and care such as the fire brigade, police forces, civil protection, armed forces and so on with an enumeration of their tasks and the way of operational coordination;

(3) the basic or extensive functional outline of the chain of emergency medical assistance with the various actions and structures in the different disaster area's such as search, rescue and first aid in the intervention zone, the medical field headquarters and advanced medical post for field care in the safety zone and a coordination committee, receiving medical facilities and reception centres in the rearward zone.

b. Tasks.

The principal tasks of the medical assistance are :

- overall coordination of health care ;
- reconnaissance with evaluation of the number of casualties and the predominant injuries ;
- participation in the evaluation of evolutive risks ;
- mobilization of medical personnel, supplies and equipment ;
- medicalization of the rescue ;
- triage, stabilization and conditioning of the casualties before transfer to medical facilities ;
- admission and treatment of casualties in care facilities;
- burial of dead bodies ;
- psychological care and social aid ;
- environmental health response ;
- preventive measures ;
- medical care in reception centres ;
- participation in the identification of casualties and corpses ;
- medical evaluation for the authorities.

c. The various functions within the chain of medical assistance together with a job description.

Such as :
- the alert centre ;
- the director of the emergency medical assistance ;
- the first mobile medical team at the scene of the disaster ;
- the second and next mobile medical teams ;
- the head doctor of the advanced medical post ;
- the head doctor of the medical evacuation centre ;
- the doctor regulator ;
- the physicians without training in emergency medicine.

d. The alarm

with the different alarmphases and the alarm threshold. The alarm threshold will mainly depend on the actual treatment and transport capacity of the emergency medical system and hospitals of a certain region but also on the number of casualties and the seriousness of the injuries. Medical assistance from surrounding regions will be necessary, if the number of casualties exceeds the capacity of the region, which corresponds from medical organizational standpoint to a disaster situation
The alarm threshold of a region will be included in the preparedness plan.

The different persons who can start and the way to start the medical action plan must also be inserted in the preparedness plan.

e. The intervention phases

According to the extent and the nature of the incident and to the expected effects or the necessary resources, the medical assistance can proceed in different phases which must not necessarily be passed through in a chronological order. For example : internal, local, regional and national medical action plans.

f. The logistics

An inventory of existing resources in manpower and material and an assessment of the needs both at the quantitative as qualitative level is necessary.

(1) Personnel

Different categories of rescue personnel can be distinguished within the chain of medical assistance according to their origin, their training and their motivation.

Schematically one can distinguish :

- medical personnel : mobile medical teams, emilitary physician, nurses, ...
- non medical personnel but with a certain medical education or training (basic life support)
  - structured corps such as Red Cross, Fire-brigade, police forces, Armed Forces, Civil Protection, ..
  - volunteers.
- temporary rescue personnel
  - involved population
  - surrounding population.

All these emergency aid personnel needs supervision and coordination.

(2) Materials

Besides the garment and individual equipment one can distinguish two categories of material : medical supplies and equipment and non medical material such as shelters, protection gear, heating apparatus, secretariat means, etc.

(3) Means of identification

It is necessary to identify executive functions and also specific functions such as physicians and nurses.

(4) Means of transport

An inventory of the different means of transport and the regional transport capacity must be included in the preparedness plan.

(5) Means of communication

It is clear that command, coordination and control within the chain of medical assistance are only possible if adequate means of communication are present because the multiplicity and dispersal of emergency aid personnel and the distances between the different echelons.

The selection of the means of communication must be based on following criteria :

- the operational importance ;
- the rapidity of functioning and the simplicity of operation ;
- the needs of turnover ;
- the security of the transmission.

(6) The receiving medical facilities

An inventory of the hospitals of the region and their actual medical treatment capacity in disaster situation must be drawed up in the preparedness plan.

g. Communication network

At least three radio networks are needed in the chain of emergency medical assistance :

- a commando network for coordination with the other rescue forces and the authorities ;
- a functional network for command, control and coordination within the chain of medical assistance ;
- a regulation network for the dispatching or distribution of the casualties.

The various radio networks can be reinforced by telephone and/or telefax apparatus.
An outline of the tactical radio network of the emergency medical assistance must be included in the preparedness plan

h. Testing and evaluation of the medical disaster plan

Regular exercises must be planned in order to test the functioning of the medical disaster plan This can be done by simulation exercises, testing of specific aspects for example the communication, or by paper and computer exercises. The frequency of the exercises must be indicated in the preparedness plan.

A methodology of information gathering in order to evaluate the disaster plan must also be included in the preparedness plan. Different techniques can be used to gather information such as reports, questionnaires, interviews, videofilms, medical records, triage tags, etc. Besides epidemiological data (number of casualties, dead, injured, involved, nature of injuries etc) evaluation generally focus upon five factors :

- structure : the personnel, the facilities and equipment and their organization and management which are available for the response ;
- process : the rescue activities and treatments provided to victims and the processes of communication, decision-making and transportation which actually were employed ;
- outcome : the degree to which morbidity and mortality were prevented ;
- adequacy of the disaster response : the proportion of victims saved who potentially could have been saved, and the extent to which the relief effort operated to its potential ;
- cost of disaster response : the total cost of the medical relief effort, the cost per persons treated, or cost per person saved.

Ideally the evaluation of the response to a disaster should address each of these evaluation categories.

6. Medical Action Plan

The medical preparedness plan will provide the medical strategy in order to prepare and execute the medical action plan.

a. Epidemiology of hazardous materials disasters (1)

Natural and manmade disasters such as hotel fires, train wrecks, airplane crashes and terrorist activities produce patients with entities such as mechanical trauma, gunshot wounds, burn and crush or blast injuries. These lesions are in general known to emergency physicians, surgeons, and ICU physicians, as well as to EMTs and paramedics. The only widely varying element in a disaster of this type is the number of patients produced.

Hazardous materials disasters, on the other hand, can produce injuries that not only are unfamiliar to physicians, but also are little discussed in the medical literature. "Toxic" hazardous materials can produce pulmonary and systemic injuries of a bewildering variety and, in addition to systemic toxicity, corrosive materials can produce chemical skin burns, which are difficult to treat.
The term "hazardous material" is used to refer to "a substance or material which is capable of posing an unreasonable risk to health, safety and property.

Many of these chemicals are toxic, explosive, flammable or corrosive, and they are skipped by truck, rail, barge, and pipe-lines. These materials may be released by accidents at any point between the manufacturer's skipping dock and the receiving facility.
Rail shipments often involve multiple rail cars carrying many different commodities. These released chemicals may ignite or react with one other and ignite or release newly formed toxic chemicals, producing a plethora of undefined products.

(1) Chemical burns

In general, chemical burns produce lesions very similar to thermal burns, with the exception that the destructive process continues until the chemical is completely removed.
It must be kept in mind that the chemical causing the skin burn may also be undergoing systemic absorption, especially because the increasingly damaged skin will allow faster absorption.
The possibility must not be forgotten that liquids may have elements or compounds dissolved in them, which, when absorbed, can cause systemic toxicity.

(2) Toxic inhalation

Inhalation of toxic gases is probably the most likely mechanism that produces multiple casualties in a hazardous materials accident, because large volumes of gas can spread rapidly over very large geographic areas.
A basic understanding of the medical management of patients with toxic inhalation injuries will help with their care. In general, it is not possible to identify an unknown toxic gas by the patient's symptoms or by physical examination.
Toxic gases, however, fall into general categories that allow one to choose overall effective treatment modalities : asphyxiants, respiratory irritants, systemic toxins, hydrocarbon compounds, agriculture poisons.

(3) Terrorism

Terrorism is violence perpetrated against people or property for political or ideological purposes. Some forms of terrorism produce no medical consequences, such as blowing up unmanned telephone or electrical power facilities, but most such acts are designed to produce mass casualties, frequently involving innocent civilians.

The form of terrorism that causes the most concern worldewide is the use of various military poison gases, given that many countries maintain large stocks of such materials, making it possible for terrorist groups to obtain and use them.

(4) Chemical warfare agents

One may initially dismiss the threat of chemical warfare agents as being of only remote interest to civilian emergency medicine physicians however, despite the active attempts of the world's international political community to outlaw their production and stockpiling, they still exist in vast amounts, as well as being simple to produce in countries having even rudimentary technical skills. Even though these agents belong to the military, many terrorist groups have access to them, with the potential catastrophe of them being used on civilians. The recent evidence of use of toxic chemical agents by military and paramilitary forces against civilian populations in Iraq and Georgia, as well as the continued threat of the use of these agents against the civilian population dictate the need for increased awareness and focused medical skills.

b. Preventive measures

To take the example of chemical accidents : engineers, psychologists, system analysts, chemists, toxicologists and health personnel are involved ; morbidity and mortality need to be studied.
Involvement of the media at all stages is important.
Harmonization of guidelines, procedures, codes of practice and regulations is required.
To prepare to meet chemical emergencies, the community must be educated and informed through messages they can understand.
National authorities in evaluating regulation guidelines, codes of practice for the safe transport, storage and handling of hazardous chemicals should involve all sectors including health.

c. Alert

The medical action plan will include an alert outline and the alarm procedures in order to mobilize the different health services, to inform the authorities and to start the medical action plan.

In chemical disasters the alert will also inform the population of a real or potential risk in order to normalize the behaviour of the population and to facilitate confining and evacuation measures.

d. Mobilization of health means

The mobilization of the various medical aid services is based on a progressive reinforcement of the local, regional and national health care systems.

e. Reconnaissance

The recce is important in order to complete the information gathered during the alarm particularly concerning the effects of the disaster :

- data on the disaster itself : nature, extent, geographic location, presence of on evolutive risk, ...
- effects on the populations .
    - evaluation of the number of casualties ;
    - evaluation of type of injuries or illnesses ;
    - accessibility and situation of casualties ;
    - situation of unharmed population.
- material effects
- structures and means still available for medical care such as :
    - structures for reception and care of casualties in the field ;
    - rallying point for the means of transport ;
    - inventory of health care facilities still functioning;
    - rallying point for unharmed population.

In chemical disasters the reconnaissance will assess the symptoms and the seriousness of the injuries, the location of the casualties and the population and the detection and analysis of toxic hazards with a risk evaluation for the rescuers, the victims and the population.

f. The deployment of the means of medical assistance

The disaster area will be subdivided into different zones which are determined by the human and material effects, the probability of an evolutive risk and the possibilities of establishment of temporary field facilities for medical care and command.

The means in medical manpower, supplies and equipment will be determined and deployed according to the needs and the availability of these means.

g. The medical field management

The medical field management start with technical actions to fight or neutralize the cause and/or consequences of the disaster. These technical actions must sometimes be carried out before the search and rescue or can be carried out simultaneously with the rescue operations.

Individual or collective protection measures for rescuers and casualties must be instituted. This requires on adequate training.

One of the important topics to be considered is the risk to the medical personnel from chemicals on the patient's skin, clothes, or both. For the most part, ordinary eye protection, and surgical mask, gown and gloves are sufficient.

Although the potential toxicity of each chemical compound, if known, to the medical personnel must be evaluated, there are certain hazardous materials that pose a higher than normal risk to the medical personnel until the patient has been decontaminated by removing the clothing at the scene and by washing.

In the event that there are many contaminated patients or that the personnel dealing with those patients are not properly trained, however, one may well find such patients arriving at the hospital still contaminated and essentially untreated. In addition some patients may arrive at the hospital by means other than the ambulances. Treating patients from hazardous materials accident is further complicated by the fact that the personnel in the emergency medical system, who have much experience dealing with mechanical trauma, generally have less experience dealing with chemically contaminated patients or patients with toxic inhalations, chemical burns or severe systemic toxicity. The upshot of all this is that the hospital may easily be inundated with patients from a hazardous materials accident who have little or no field treatment.

(1) Triage

Triage can be defined as a selection that determines the order of priorities of evacuation and treatment in order to use as adequate as possible the available resources for stabilization, conditioning and evacuation of casualties and this for the benefit of the largest number of casualties.

Casualties can easily be classified according to the nature of the injuries. Not only the nature but also the extent and the seriousness of the injuries, the existence of associated or combined injuries, the mechanism of injury, the prognosis, comorbid diseases and age must be taken into account to perform an appropriate triage. The decision process of triage becomes even more complex in disasters in which factors such as hostile environmental conditions, time, resources in manpower, material, means of transport and receiving medical facilities must be taken into consideration. Sorting is thus a dynamic process and must be repeated throughout the chain of emergency medical care taking into account all factors of the triage process.

The military categorization procedures are the only triage methods which have proven their efficacy in mass casualty situations. These military sorting procedures must be adapted to disaster pathology and civilian logistics.
To achieve the objective of providing the greatest benefit to the largest number of patients, casualties should be triaged into following categories :

(a) Immediate treatment group - T1

Casualties with disorders of vital functions or in need of emergency life-saving surgery but with high chance of survival. The treatment procedures may not be time-consuming. In chemical disasters : asphyxia, major respiratory failure, burns with a lethal risk (20 - 50% TBSA), coma due to systemic toxicity.

(b) Delayed treatment group - T2

Casualties requiring treatment in hospitals, but their clinical condition allows a delay of treatment without endangering life. Sustaining measures (stabilization) will be administered in order to mitigate the effects of delayed treatment. In chemical disasters : initial severe irritation of respiratory tract tissues with progressive improvement, burns requiring hospitalization for specialized burn care.

(c) Minimal treatment group - T3

Slightly injured and/or ambulatory casualties who need little care which often can be given by non specialized personnel. In chemical disasters : brief exposure to hazardous materials, rapidly resolvent disorder of consciousness after return to normal atmosphere, minor superficial burns.

(d) Expectant treatment group - T4

Severely injured casualties, often with multiple injuries and with very poor or no chance of survival. They may not be abandoned to their fate, but a so-called comfort treatment will be administered. As some casualties may have a minimal chance of survival, definitive treatment will be given as soon as the mass casualty situation is under control. In chemical disasters · cardiopulmonary arrest, extensive burns (> 50 % TBSA) or burns with lethal risk with major respiratory failure.

(2) Stabilization and conditioning of casualties

Stabilization and conditioning for transport may be necessary in view of the important impact on the outcome of the casualties. Stabilization prevents numerous premature deaths, can prolong the time available for primary care and can result in a change of priority group.
The care on the scene of the disaster must however be restricted in order to not delay the evacuation a nd hence the definitive treatment in medical facilities.

Stabilization and conditioning on the scene of the disaster must remain simple in order to allow an easy adaptation to unexpected situations.
The treatment procedures must be similar to those used in the every-day emergency medical system in order to achieve an immediate and efficient response.
Stabilization and conditioning will be restricted to the preservation of cardiorespiratory functions without the mobilization of too important resources in manpower and material, restricted to the control of bleeding and the prevention of shock, to splinting of fractures, dressing of wounds, to analgesia and to prevention of hypothermia.

Copious lavage with water is the key to the initial management of chemical burns, which would be started in the field and continued at the hospital.
Some chemicals that cause cutaneous burns have well defined lesions and treatment.
Specific medical information about the toxicity of the gas or gases probably will not be known at the time medical personnel begin to treat casualties. On the other hand hazardous materials accidents involving toxic gases most commonly involve chlorine, ammonia and hydrogen sulphide, about which information concerning medical treatment is well known.

Field management will therefore mainly consists of a symptomatic treatment. Nevertheless some of these intoxicated casualties need specific antidotes in order to alter outcome and decrease morbidity

(3) Regulation and evacuation of casualties

Regulation and evacuation of casualties to the most appropriate medical facilities is an integral part of triage and an important link in the chain of emergency medical care.

Medical regulation is the process which coordinates the evacuation of casualties from the site of disaster to the medical facilities.

Factors which can influence the regulation process are :

(1) treatment capacity of medical facilities ;
(2) specialized treatment capacity such as burn centres;
(3) means of transport ;
(4) time limit for treatment ;
(5) distance to the medical facilities ;
(6) number and clinical condition of casualties.

Efficient communications are critical in the regulation of casualties to appropriate medical facilities.

The casualties will be evacuated in appropriate means of transport with appropriate surveillance.

In chemical disasters, regulation and evacuation must take into account the possibility of contaminated casualties.

h The receiving health facilities

Treatment of disaster casualties in medical facilities is the final purpose of the chain of medical assistance.

In a mass casualty situation the problems and the response for treating the casualties will be quite different according to the degree of preparedness of the hospital to receive a great number of casualties and according to the prior stabilization and conditioning of the casualties before their arrival in the hospital.
Consequently the normal structure and functioning of the hospital must be adjusted to the mass casualty situation and anticipated in a hospital disaster plan.
There will be architectural adjustments : a circuit for ambulances, a large reception area, an intrahospital circuit of casualties, transformation of some departments, etc ;
Some specific departments or services must be established or reinforced : telephone central, reception and information centre for families and media, coordination centre, etc

Quantitative and qualitative reinforcement in manpower will be neccessary : administrative personnel, care personnel, catering personnel, etc ...; and also a reinforcement in drugs, medical supplies and equipment according to a prior study of the various hazards in the region.

Since many contaminated casualties can arrive at the hospital, protection and decontamination measures must also be included in the hospital disaster plan.

References

1 R B Leonard and U. Teitelman : Manmade Disasters, Critical Care Clinic, 7, 293, 1991.

2. R. Nota et al : Medecine de catastrophe. Ed by Masson, 1987, P 43.