Attachment 5

CONCEPT-REPORT NATO-CCMS Pilot Study "Disaster preparedness for responding to chemical accidents"

CHAPTER 2. HEALTH HAZARD ASSESSMENT (continued)

Heat radiation consequences for people

The models derived for the calculation of heat radiation consequences for people are based on empirical relations. The probability to die when a certain percentage of the body area is burned, strongly depends on the age. The consequence models, however, are based on an average population.
The severity of the injury from heat is determined by the depth in the skin to which a temperature difference of 9 K has occurred:
first degree burns < 0.12 mm
second degree burns < 2 mm
third degree burns > 2 mm

On the basis of empirical threshold values, probit functions have been derived for first and second degree burns as well as lethality for both unprotected and protected (clothes) bodies. The protection of clothes of course is only effective until the moment of ignition of the clothes. It is assumed that about 20% of the body area remains unprotected. On the basis of an average population this leads to a lethality of 14% of the lethality percentage for unprotected bodies.

Probit functions for heat radiation

First degree burns $Pr = -39.83 + 3.0186 \ln t.q.^{4/3}$
Second degree burns $Pr = -43.14 + 3.0188 \ln t.q.^{4/3}$
Lethality (unprotected) $Pr = -36.38 + 2.56 \ln t.q.^{4/3}$
Lethality (protected) $Pr = -37.23 + 2.56 \ln t\,q^{4/3}$

t : (effective) exposure time (sec)
q : heat radiation (kW/m^2)

Effective exposure time for heat radiation

Accident analysis studies (e.g. Mexico City) show that the influence of running away and seeking protection behind obstacles very significantly influences the heat radiation consequences. The following relation is given to determine the duration to reach a safe distance ($1\ kW/m^2$)

$$t_{eff} = t_r + 3/5\ .\ x_0/u\ \{1 - (1 + u/x_0\ .\ t_v)^{-5/3}\}$$

t_r = reaction time (5 seconds)
x_0 = distance to centre of the fire
u = run speed (m/s)
t_v = time to reach $1\ kW/m^2$ distance

2.4 Decision Support and Reporting Systems

2.4.1 Introduction

In the first part of this chapter, attention was given to the models that are available to estimate the effects and consequences of a specific accident. The next step is how to make these models suited for use under operational circumstances. In order to ensure effective and efficient emergency response, those in charge of the emergency management have to be provided with accurate and correct information about the nature and size of the accident. Furthermore, the emergency management has to make decisions about which countermeasures have to be taken. This requires the ability to make a quick balance of the pros and cons of different response strategies. Many decision makers become rather hesitant when they are faced with such a situation, either leaving the decision to their employees or even completely failing to take a decision

To help decision makers in their difficult job. so called "decision support systems" (DSS) have been developed This term perfectly indicates what a decision support system is supposed to do. it offers support in making a decision. That means that the DSS does NOT replace the decision maker: the person him/herself is the one who is finally responsible for the decision. In making the decision, aspects may be taken into account that are not incorporated into the DSS, such as social or political motives. These aspects are often hard to quantify, and it is up to the decision maker to give them proper consideration.

Often it is thought that a DSS is an automated system (i e. some piece of computer software). This, however, is not necessarily the case. Handbooks, written procedures, maps, protocols and other paper material can provide very useful decision support. The only reason that automated systems have been (and are being) developed, is that they increase the accessibility to large databases and that a computer can rapidly perform calculations

However, there are some disadvantages to automated systems:

- Databases need maintenance; especially geographical information will change rapidly in time Databases containing properties of chemical substances may be subject to changes, especially for those chemicals that are not very well known. For many chemicals, toxicity data are lacking, or only rough estimates are available. If these data become available or are improved, the database has to be adjusted
- The effect and consequence models are continuously being refined, which means that from time to time new versions become available, giving more accurate results. A DSS user may want to incorporate these newly developed models into the system.
- To use a DSS requires training; most decision support systems are too complicated to use them for the first time in an emergency situation with one eye on the computer screen and the other on the manual. This means that there must be at least one person (and preferably more) who is really familiar with the system
- The final and maybe most important disadvantage of a computerized DSS is, that although everybody knows that it is "only" a computer, the DSS is seen as an oracle speaking the ultimate and utter truth. The results of a DSS are mere estimates, indicating the possible dimensions of the hazard area and the order of magnitude of the number of casualties

In spite of all this, we may say that in many cases a computerized DSS has big advantages Large stocks of information are rapidly accessible, huge amounts of data can be processed quickly and the results are displayed in an orderly fashion, be it alphanumerically or graphically. In an emergency situation many people have to be informed; the computer may establish connections automatically (via telephone or fax), and will call everybody on the list without forgetting a single person... Hard copy messages may be generated and distributed promptly to those needing them. Provided the requirements in terms of (personnel) time and money are met, a computerized DSS will greatly enhance the performance of the emergency management organization.

2.4.2 Components of a decision support system

Let us now turn to the elements that may be present in a decision support system.

* **Registration of accident information**
The first emergency response activity is to establish an "accident diagnosis". This means that the relevant information has to be reported and registered (location and time of the accident, chemicals involved, casualties, injured, weather, etc.).

* **Providing product/material information**
One of the databases in a DSS will contain the physical and chemical properties of a (large) number of hazardous substances. There are two categories data that are used as "practical information" to the user (e.g. appearance at room temperature (liquid, powder, crystalline, etc.), liquid density (does the substance float on water?), reactivity, flammability,...), and properties that are required for the model calculations. Properties of the latter category may be temperature dependent (such as specific heat, gas or vapour density, etc.), which means that the software must contain an algorithm to calculate the property value for the temperature in question
Another important part of the database will contain the toxic properties. They may be qualitative (just a verbal description) or quantitative in the form of specific values (LD_{50}, LC_{50}, STEL, TLV, IDLH) or as a mathematical relationship between exposure time and concentration (or "dose") and response fraction.

* **Providing geographical and/or demographical information.**
To get a good overview of the accident site a map of the environment may be very helpful. Therefore, most decision support systems contain a mapping facility. Basic topographic information may be combined with data on population density, transportation routes and special objects (industries, hospitals, schools, sport stadiums, etc.).
In addition, a DSS may provide background information to the special objects (names and addresses, hazardous substances present, numbers of people present at what time of the day, facility floor plans, etc.).

- **Effect and damage calculations.**
  Dependent on the models that are incorporated into a DSS, calculations of the physical effects (outflow and spread of the chemical) and of the consequences (health effects, material damage) may be carried out. Most systems do not contain consequence models and give as a final result the concentration contours around the accident site (e.g. CAMEO; the IEMIS, developed by FEMA, contains dose response-relationships for radioactive materials but not yet for chemicals). In those systems that perform health effect calculations, population data are combined with the concentration contours as a function of time to calculate the (toxic) load; the response percentage is often determined making use of probit functions. The results of consequence calculations are given as numbers of victims (casualties, injured).

- Evaluation of different countermeasure strategies.
  For a specific accident a number of different emergency response strategies may be chosen A common measure is to advise the population to find shelter; however, under certain circumstances evacuation may be an alternative. A DSS may give an impression of the consequences of both strategies in terms of numbers of casualties If the DSS shows the increase of the number of casualties with time, this may provide insight into unexpected effects. For instance, if people have been sent indoors upon a toxic gas release, the protective effect of the building may disappear some time after the toxic cloud has passed over the area. This will be seen immediately in a table showing the growth of the number of victims in time. Such information may help in establishing the moment for sending out a message that people have to leave and ventilate their homes.

- Providing operational information.
  The results of the effect calculations may be useful in determining the best material supply routes, collection locations, etc. A graphical display of the contour of a gas cloud indicates immediately those parts of the surroundings that are in the hazard zone. Possible locations for field headquarters etc. may be indicated, all which is providing very useful information for the emergency management.

- Performing automatically emergency response actions.
  In a more complicated emergency situation a large number of operational services plays a role. This means that many people have to be informed about the situation. A non-automated emergency response plan will contain a list of names and addresses; the people on this list have to be called by phone or reached by fax. A computer may establish the connections automatically, and will call everybody on the list without forgetting a single person... Manpower otherwise involved in this (often tedious) job can now be used in other activities.

Another function of an automated DSS is generating hard copy messages, containing text, chemical property information and maps of the hazard area, and distributing them promptly to those needing them. This ensures that complicated information is spread quickly and without errors.

2.4.3 Examples and short description of non-automated DSS

There is a great variety of non-computerized decision support instruments. Nearly every alarm post or emergency response service will have them available: registration forms, handbooks of all kinds (chemical and physical data, toxicological information such as RTECS or "Dangerous Properties of Industrial Materials" by N. Irving Sax, CHRIS, etc.), military or other maps, descriptions of procedures to be followed, report protocols, and so on.

A special non-automated decision support tool that is used in the Netherlands is the so called "Hazard Contours", indicating the concentration or the consequence distances for a specific release. The hazards have been categorized, and the user must answer a limited number of questions before arriving at a certain Hazard Contour The Contours are printed on transparencies that may be used as an overlay on a map of the accident area.

2.4.4 Examples and short description of automated DSS

In the last few years, many computerized decision support systems have been developed, with varying features and for different hardware configurations. Some examples of commercially available systems are·

- SAFER (Systematic Approach For Emergency Response), developed by SAFER Emergency Systems, which is now part of the Du Pont Company; it runs on a microcomputer, and contains a Lagrangian trajectory dispersion model including complex terrain and dense gas dispersion; dosage can be calculated, but numbers of victims are not given; automatic connections with relevant authorities/persons

- MIDAS (Meteorological Information and Dispersion Assessment System), developed by Pickard, Lowe and Garrick, Inc ; there are three versions regarding the hardware, varying from a PC to a large minicomputer (Tektronics); dispersion is modelled by a Gaussian straight line plume model, a Gaussian variable trajectory plume model or a Lagrangian particle tracking model (including dense gas dispersion); final results: concentration contours;
  (NOTE: the MIDAS system must not be confused with MHIDAS, a databank containing information on major hazards, which is an activity of the British Health and Safety Executive (HSE) in conjunction with the Safety and Reliability Directorate (SRD)).

- CHARM (Complex Hazardous Air Release Model), developed by the Radian Corporation; it runs on an IBM-PC and contains a specially designed dispersion model; concentration contours; listing of relevant contacts.

In a number of countries the authorities have developed or commissioned the development of a DSS. Examples are·

- CAMEO (Computer Aided Management of Emergency Operations), developed by the National Oceanic and Atmospheric Administration (NOAA) and the US

Environmental Protection Agency (EPA); CAMEO has been developed for an Apple PC, but meanwhile also runs on IBM-compatible PCs; it contains the ALOHA dispersion model;

- IEMIS (Integrated Emergency Management Information System), developed by the US Federal Emergency Management Agency (FEMA); the IEMIS is a large system, originally developed as a part of the Radiological Emergency Preparedness Program; it consists of a complete database management system, effect (also fire and explosion) and (radiological) consequence calculation models, graphical options and facilities for communication with other users/regions; runs on a VAX 11/750 minicomputer, serving 15 field workstations located in the Regional FEMA Offices.

- IRIMS (Ispra RIsk Management Support System), developed by the EC Joint Research Centre at Ispra, Italy; the models are extracted from the risk analysis software package SAFETI, by Technica Ltd ; Lagrangian dispersion model; runs on a Sun microcomputer;

- SEABEL has been developed by TNO (Netherlands), commissioned by the Dutch equivalent of the Coast Guard, Rijkswaterstaat, it is to be applied for emergencies at sea; it runs on an IBM-PC, and calculates concentration contours; the system contains an automatic contact module, at the moment it is being installed in the member states of the EC

- IRIS (Netherlands) is developed for the Fire Inspectorate of the Dutch Ministry for Internal Affairs. It is a decision support system which enables the user to evaluate countermeasure strategies by comparing estimated numbers of casualties (deaths and injured). It consists of a complete database management system (SYBASE), effect models (a.o. Gaussian puff dispersion model AVACTA) and consequence calculation models and graphical options (GKS) It runs on a DEC MicroVax. The chemical database contains data for nearly 100 hazardous substances. IRIS does not provide automatic connection facilities.

2.5 Sampling

In accident situations it is important to get an impression of the concentrations of hazardous gases in the air near the location of the accident. If there is a flammable gas cloud that has not yet been ignited, it is essential to know in which area ignition sources must be avoided or switched off. In case of a toxic release, in the area where certain threshold concentrations are reached people may be told to go indoors or even to evacuate.

Sampling equipment exists for both explosive and toxic gas mixtures. Equipment may be portable as well as stationary, for continuous measurements. In case of an accident, a portable measuring device will mostly be preferred. Portable measuring equipment may, generally speaking, be less advanced than a stationary facility: its measurement accuracy may be less, and the processing of data will often have to occur by hand (e g transmitting measurement results over the telephone, which is a possible cause for errors).

An example of manually operated gas detector measuring devices are the Drager gas detectors. They consist of a hand-operated bellows pump, equipped with a detector tube for the specific material to be detected The working mechanism of a Drager detector is that of a dosage pump: by operating the pump, a gas sample is sucked through the detector tube and simultaneously the sampled volume of air is measured Dependent on the substance of interest, one or more strokes are necessary (up to 200 strokes per measurement). The concentrations that may be measured range from mg/m3 to even ppb-level (ca. 10^{-9} - 10^{-7} mg/m3).

An example of a more advanced portable measurement device is the German "Spurfuchs" ("trace-fox"), which is a car with advanced equipment. This car is unfortunately rather expensive. However, it offers the opportunity to measure in the field and process the data on the spot. An important aspect of measurements is the distribution of sampling points, which influences the predictions Dependent on the prediction techniques used, a minimum number of sampling points with a minimum spread in time as well as space is required. This part of the prediction models is still strongly in development.

2 6 Health Plan Development

2 6 1 Definition

The definition of a health plan depends on the point of view Somebody who is in charge of the health care in emergency situations will tend to see the health service as the most important part of the emergency management organization A fire chief or police commander, on the other hand, will stress the contributions of their respective organizations. Most important, however, is that those who are involved in an emergency are properly rescued and taken care of. This is the one and only job that is to be done after an accident, and it is the responsibility of the emergency management organization as a whole, not just of one of the individual organizations.

Therefore, the integrated emergency management concept should be adopted. This means that the organizations involved have to be working together in all phases of the emergency management cycle. in prevention, preparation, response and recovery. Since we have seen an excellent example of this concept in Louisville, Kentucky, I need not go into more detail about it. One of the main features of such a concept is to be highlighted: integrated emergency management is not a static situation but a continuous process. It needs ongoing development and continuous exercise, not only because of changing situations, new data and materials becoming available and personnel replacement but also to keep everyone involved alert.

2.6.2 Contents of a health plan

What should a health plan look like, that is to say, which elements should it contain at the very least?

First of all, in a health plan attention should be paid to identifying the potentially hazardous situations. This can either be done in a fairly simple way, by brainstorming with a number of local "experts" who are familiar with the situation in a community or in a region, or by using more advanced techniques such as a risk analysis, especially when complicated industrial installations are present. In such a case, it may be worthwhile to calculate the possible consequences of a hypothetical accident (e.g. a fire or a toxic gas escape). In performing these calculations, the effect and consequence models discussed in this chapter have to be used. If there is the need for setting priorities, also attention may be given to the probabilities involved.

For the health service part, it is important to get an impression of the maximum number of casualties that might occur in order to judge whether the capacity of the local medical services (ambulances, hospitals) are sufficient. In this phase, attention must be given to the cooperation with services and hospitals in neighbouring regions.

If really hazardous situations are identified, it may be decided to impose risk reducing measures such as installing safety devices, process changes or even a complete plant shut down

Another result of the identification phase is that a proper estimate can be made of the response capacity that is required A material maintenance plan is essential Also, the organizational picture for the most important accident situations should be drawn up, and the people involved should be exercised on a regular basis This is what is called "preparedness": knowing the needs and keeping the personnel and material in good shape.

In an operational situation a health plan should provide information on those responsible for the different tasks to be performed. Furthermore, a decision support system, be it a paper version or an automated system, may be of a great help in determining the optimal countermeasure strategy By calculating the expected numbers of casualties (again by using the effect and consequence models presented in this chapter) and comparing the results of different tactics with respect to the accident development, the strategy resulting in the least number of victims may be chosen

Furthermore, predictions of numbers of casualties may be very helpful in determining the required ambulance and hospital capacity

A health plan should contain elements about the actions to be taken in the recovery phase. These will not only be concerned with the (after-)hospital care for the injured, but also with counselling of response personnel, and with social or psychological help for those who are not immediately involved but who have suffered indirectly from the events (for instance the relatives of the deceased). And in the recovery phase conclusions will be drawn as to the performance of the emergency services as a whole. New plans may be developed, new material purchased and personnel (re-)educated and trained. Which brings us back to the first phase of the emergency management cycle.

Attachment 6

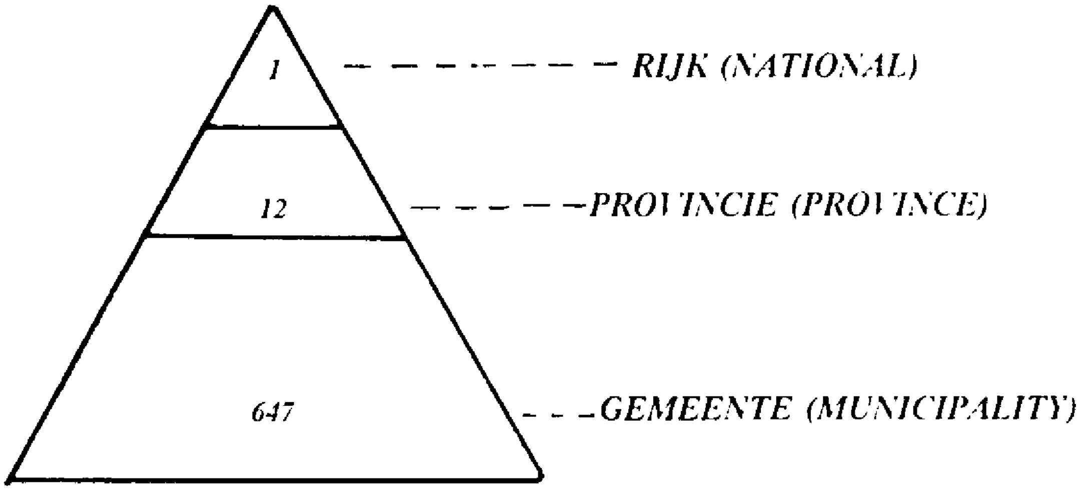
CCMS PRESENTATION

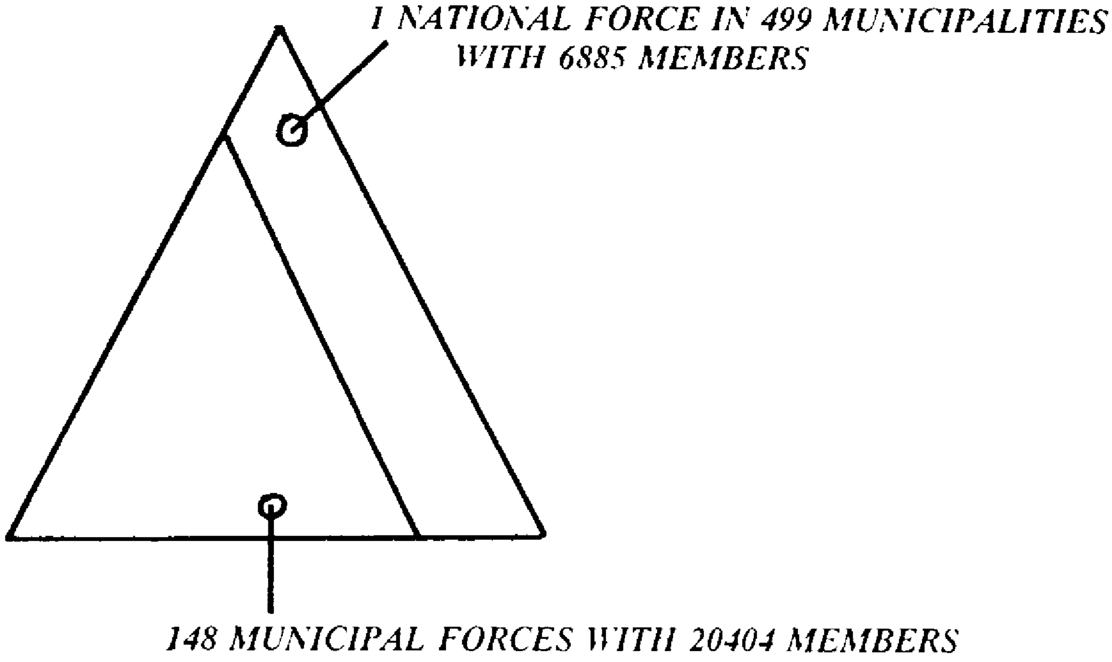
20 MAY 1992

L. de Bruijn

"The Dutch Program for Handling
Environmental Aspects of Chemical Accidents"

1.

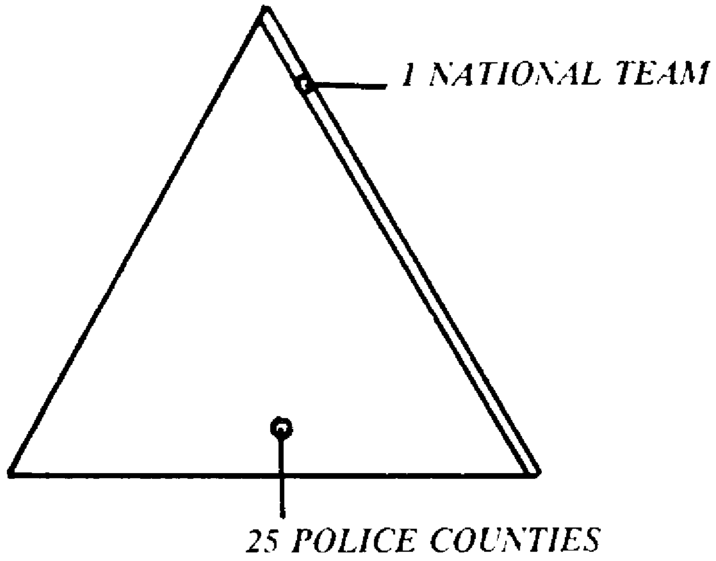

1
RIJK (NATIONAL)
12
PROVINCIE (PROVINCE)
647
GEMEENTE (MUNICIPALITY)



(ALSO ± 11.000 ADMINISTRATIVE WORKERS)

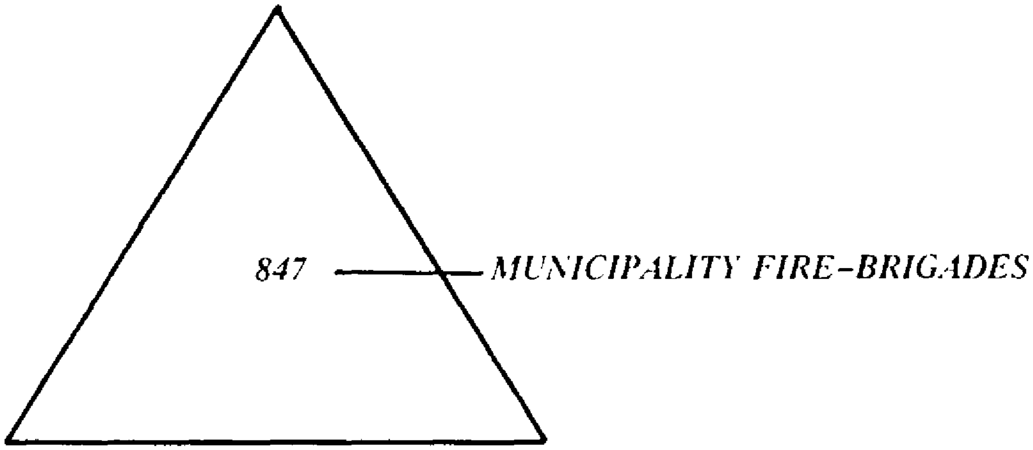
3.

POLICE 1993 –



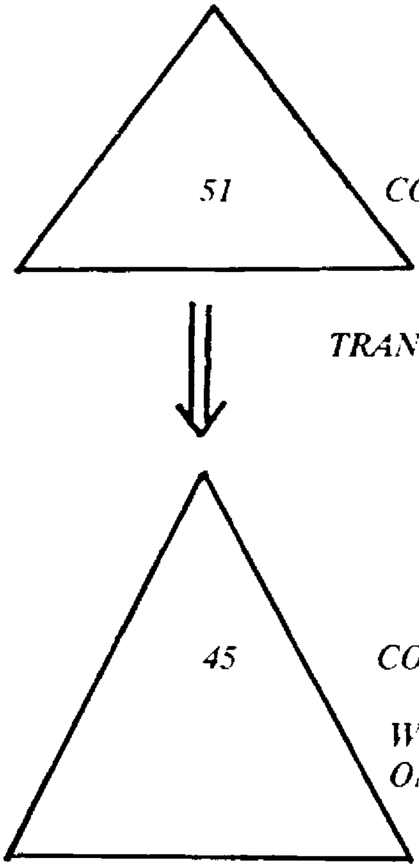
4.

FIRE - BRIGADE ——— 1975



ALSO 45 CIVIL-PROTECTION COUNTIES

FIRE BRIGADE PLAN 1980



51 COUNTIES

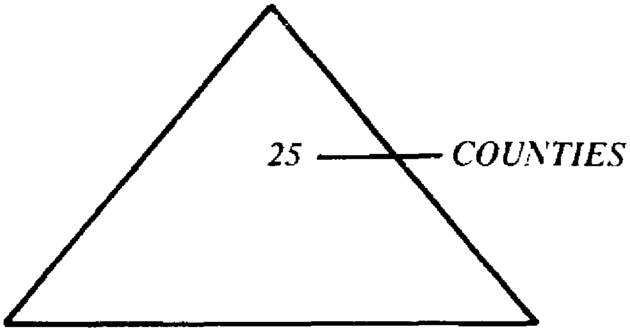
TRANSFORMED 1990

45 COUNTIES

WITH 26.000 MEMBERS
ONLY 2700 FULL TIME PROFFESIONAL

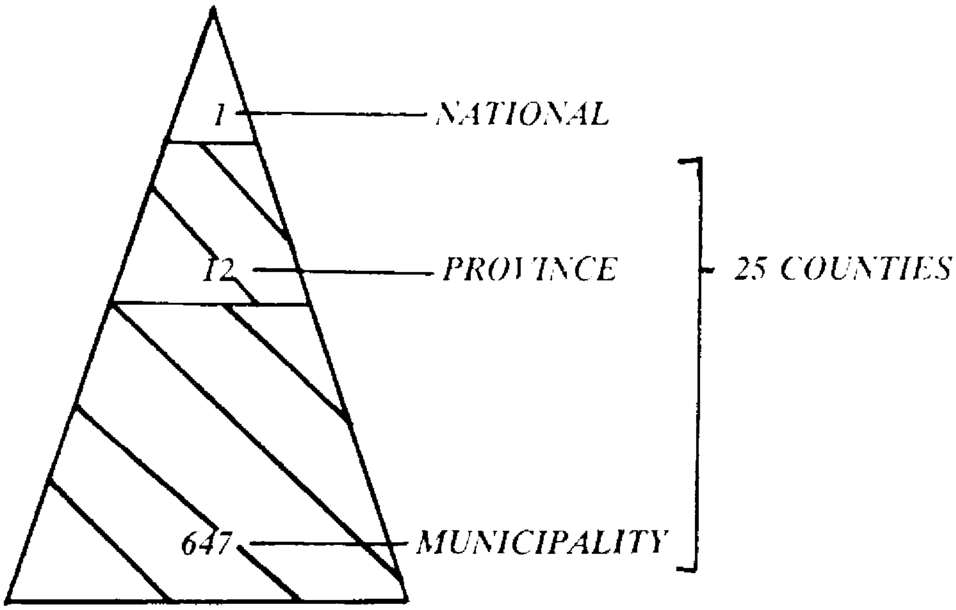
45 JUST CO-INCIDENTAL NOT THE OLD 45 CIVIL PROTECTION AREAS

NEW PLAN FIRE BRIGADE (18 FEBR. 1992)

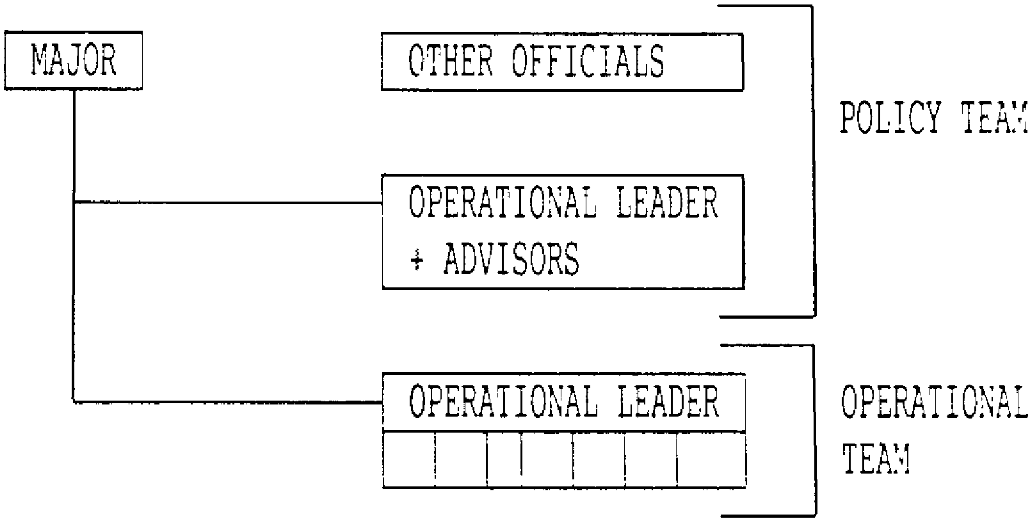


THESE 25 COUNTIES SHOULD BE THE SAME AS THE POLICE COUNTIES.

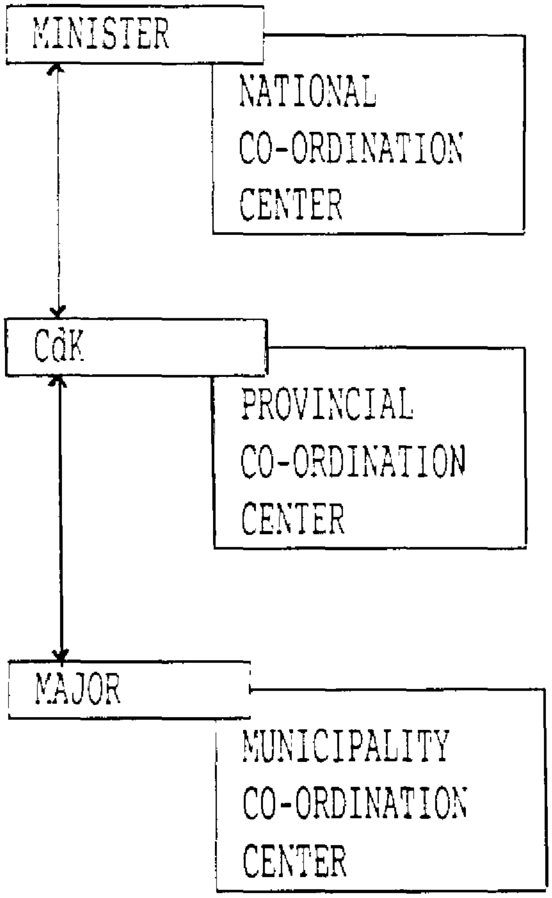
COUNTIES WILL BE FORMED OUT OF PROVINCE AND MUNICIPALITY.
BUT PROVINCE AND MUNICIPALITY WILL NOT DISAPPEAR.



EMERGENCY STRUCTURE MUNICIPALITY



EMERGENCY STRUCTURE NATIONAL



"El documento original contiene páginas en mal estado."

"The Dutch Program for Handling Environmental Aspects of Chemical Accidents - POBM"

The best way to address the present Dutch program for handling chemical accidents is to first provide a brief history, outlining the process that existed prior to the formation of our project so that you can best understand why this project came into being and then addressing the scope of what we are presently doing, within the project, to develop and implement a total National program for response and environmental management of chemical accidents. Although the Chernobyl accident was radiological in nature and not chemical, as we all are aware, this accident served as a trigger for National attention in the Netherlands to emergency preparedness; and thus is a fitting starting point for our discussion.

I. Pre-Chernobyl

A. Preparedness was a Municipal responsibility, little to no coordination or integration between municipalities and upward with Provincial/County or National/Federal government existed. The level of preparedness at the Municipality level varied greatly, with some cities having extensive plans and programs in place, while the majority had no formal plans or programs.

B. The primary response was by Fire Brigade personnel with the Municipal Mayor/Burgemeester as the responsible individual in charge - Fire Chief in-charge at the accident scene.

C. Planning and Preparedness was essentially up to the individual Municipality, no guidance/direction or support was provided or mandated from industry or government beyond the Municipal level.

II. Post-Chernobyl - pre-POBM

A. Establishment of project to develop a Plan and program for response to Nuclear Emergencies/Accidents (PKOB); this resulted in the development of a National Plan for response to nuclear emergencies for the nuclear facilities (Borssele and Dodewaard) in the Netherlands and addresses response to similar types of possible accidents at those facilities bordering the Netherlands as well as any nuclear type emergency that could arise, for whatever reason, that does or could impact the Netherlands. This Plan provides for a coordinated and integrated response organization, with associated lines of responsibility based upon the severity of the accident, from the affected Facility and Municipal level of government up to and including full National response.

This Plan was completed and published in 1989 and went into effect this year following a staff exercise conducted in November of last year, to test the adequacy of the Plan for the Borssele Nuclear Facility.

B. Although major accidents/events (chemical or nuclear) necessitating coordination beyond the Municipal level of Government are very few; in the 80's several incidents necessitating coordination between police and fire brigade organizations demonstrated a need to reorganize these groups beyond strictly a Municipal level. As a result, in the late 80's, these organizations were reorganized into regional groups. This reorganization presented several new problems:

1.) The regions were different for the police and the fire brigades.
2.) The regions were not based upon any government boundaries.
3.) Although it was determined that the Mayor of the largest Municipality within the region would be in charge; in effect, no one was truly in charge except for the regional police/fire brigade commanders.

C. Several National Organizations (Ministeries, Departments) commenced development of or upgraded their own specific emergency response Plans and/or level of preparedness, particularly for those organizations involved in the transport sectors (shipping, rail, and highway). For the most part, the plans and programs were setup independently from each other; any level of coordination was based upon the personal contacts of various members of these organizations carrying out the task of developing/upgrading the plans.

I must note at this time that the National organizations are also setup in a regional and/or Provincial arrangement; those which are established regionally are based upon their area of responsibility, i.e. major shipping along shipping lanes, rail and truck/vehicle transport along major transportation routes. Hence, a similar situation arises as with the Police and Fire Brigade regions.

III. POBM

In 1990, the Ministeries of Housing, Planning and the Environment (VROM) and of the Interior (BIZA) recognized the need to integrate these plans and programs to provide some level of assurance that the Country, as a whole, was prepared to respond to and handle any type of accident and to provide some level of response and coordination for major events at the National Level. This led to the formation of POBM (The project to develop a program for Total response and preparedness for Chemical type accidents).

A. Phase I

The Ministeries of VROM and Biza were charged with the lead responsibility to accomplish the goals of POBM. In essence this goal was to ultimatelt develop a Plan and program, similar to the NPK but obviously addressing the needs of response and environmental management for a chemical, not nuclear, event. The first step was to establish project Coordinators within both Ministeries and provide them with the tools, resources, and authority necessary to accomplish this goal.

By early 1992 the project coordinators were selected and had developed an initial plan for accomplishing the project goal The first phase of this plan consisted of determining the existing state of preparedness throughout the country and assessing the true level of need or the Risk of accidents within the Netherlands. To accomplish this first phase, four working groups were established, each having a specific area to look at

1. Global Risk assessment with emphasis on impacts to the Netherlands

2. Status of Plans, programs, preparedness for managing chemical events

3. Inventory of present capabilities and resources for responding to and handling the environmental consequences of a chemical event

4. Status of Plans, programs preparedness for "first-response" organizations

The Project Organization, as well as the make-up of the working groups, are found as Attachments 1 and 2 respectively I should mention, at this time, that although this presentation is focusing on POBM as the project for developing a program for handling the environmental consequences of a chemical accident, the full scope of POBM includes the day-to-day handling and response to any non-nuclear, environmental problem, including food soil, water, building contamination problems or suspected problems Over the past year, we have dealt with numerous environmental issues - all of which were handled in an ad-hoc basis The handling of these situations has fortified our commitment to and recognition of the need to have a formal, well-developed program in place

The conclusions of the working group tasks were essentially what I have mentioned previously in addressing the pre-POBM status These conclusions were developed into a summary report, presented to the Ministers of VROM and BIZA, and will be discussed at a Phase I closeout/Phase II kickoff workshop on 23 June

B. Phase II

The results of Phase I clearly indicate the need to develop a POBM NPK type document This is the goal of Phase II Although formally commencing and being developed on 23 June, via the workshop, our proposal for accomplishing this goal during Phase II is as follows:

Four working groups are to be established,

Group I - A scenario development working group with the charter/goal to develop accident sequences which encompass (1) the results of the Risk

Assessment Group from Phase I, and (2) a reasonable number and types of accidents which will adequately address all response modes for "first-responders", Regional, and National Government.

Group II – A National Organization group with the charter goal to address the most effective manner for National response – both from a management level and from a "first-response" support level; the latter is especially critical where speciallized expertise and laboratories are needed.

Group III – A Regional Organization group with a similar charter goal as group II, but obviously focusing on the immediate, local, and regional response.

> Note: Groups II and III are to develop an initial concept; this concept will be "tested" using the scenarios developed by Group I. At this time it is envisioned that this will be accomplished by a combined meeting of groups II and III where the scenarios will be presented under controlled conditions and the concept organizations will need to respond and manage the events in an integrated fashion.

Group IV – A Crisis Management Information Data Systems group with the charter/goal to evaluate and ultimately put in place a Nationwide, integrated, networked crisis information management system.

Our goal is to complete this Phase of the project with the completion and issuance of a Plan, by the end of 1993. This is to be followed by testing of the Plan and development of the program in 1994.

CHAPTER II

Attachment 7

ENVIRONMENTAL HEALTH ISSUES

I. Background

Man has used chemicals since the beginning of recorded history. Among the first were pigments used for decoration, following by the development of metals for use as weapons, containers and religious decorations. With these chemicals, and others that followed, has come first the presence and later the recognition of disease entities associated with excessive exposure, whether from their manufacture, use, or disposal.

Toxicity from lead, one of the first of such recognized diseases, was initially described by a Greek physician in the second century B.C. Plinny in the first century A.D. described lung disease associated with the use of asbestos fibers to make fireproof tablecloths as "the disease of slaves". The potential political utility of chemical toxins was just recognized in first same period with the popularization of criminal poisonings in the first century A.D. With the fall of the Greek and Roman empires environmental toxicology, like most scientific pursuits entered a hiatus until the late middle ages where Ramazzini (1633-1714) in Italy began the modern study of occupational medicine by associating occupations and environmental chemical exposures with disease processes.

Within our most recent decades we have been made acutely aware of the toxic potential of chemicals in our environment by such natural and man-made disasters as Yucho (1968), Sevesco (1976), Bhopal (1984), and Lake Nyos (1986). Such disasters have added new terms to our toxicology lexicon-terms such as the Minamata Bay Disease (mercury poisoning) and Yusho Disease (PCB poisoning) and superfund sites to name but three.

While disease association with large, well defined chemical exposures at relatively high doses is often very clear cut, making such associations under other conditions may be extremely difficult. This inherent difficulty arises from a number of basic scientific difficulties which need to be discussed in order to put our limited human health data base into perspective. For a small group and a limited event it may be clear which individuals received an exposure. However for very large groups, such as populations adjacent to chemical releases, it may not be clear that all individuals are exposed at all, let alone that they have exposures of equivalent magnitude. Thus, attempts to establish a relationship between a particular chemical exposure and any disease incidence in that population may be distorted by the inclusion of many individuals who were not, in fact, exposed. This effect is compounded by a second basic problem of defining cause-effect relationships in chemically induced illness, latency. Particularly for chemicals causing malignancy, either directly or as the result of indirect mechanisms such as the production of immunodeficiency, there may be a period of 20 years or longer between the exposure and the overt presentation of the disease. Thus exposed populations may need to be followed by medical surveillance for extended periods in order to ascertain a cause-effect relationship.

Once there is evidence of a cause-effect relationship between a chemical and a particular disease, it becomes necessary to define the relationship between the amount of exposure and either the frequency or severity of the resulting disease process. This process is hampered by the technical and practical difficulties of quanitating exposures. The scenarios of concern may involve either acute or chronic chemical exposures. However, for neither case is there usually relevant data which would allow, using modeling, even a crude estimate of total exposure. Sampling and analysis, if done at all, are usually done at discrete times and locations. Extrapolation to other sites and locations is difficult and problematic. Even when frequent or continuous monitoring data is available, such as in the occasional occupational setting, actual penetration into the body depends on such factors as age, sex, respiratory rate and volume, temperature, skin permeability and surface exposure, and chemical concentration in air or water. Recent attention has been directed at more individual estimates of exposure via the monitoring of urine or blood concentrations of chemicals or their biological degradation products.

Quantifying a dose-response relationship is further complicated by a well-recognized and accepted variability in individual response. All individuals do not generally respond in an identical manner to any particular chemical exposure, assuming that the exposure is not uniformly fatal. The relationship of exposure to response can usually be roughly depicted by a sigmoid curve. Dose response relationships may also be confounded by the presence of other relevant variables and background. That is, we must distinguish the effects of a given chemical from similar or identical effects that may derive from other chemicals in the environment as well as from the frequency of the particular effect which may occur in a totally unexposed population.

All of these effects contribute to the uncertainty that often surround both the qualitative and quantitative associations of a chemical with a disease.

With this background from where does the data derive on which health decisions are based in chemical exposure incidents? The limited data which does exist for most chemicals in fact derives from three sources: animal experiments, occupational exposure data and data from prior accidents.

For most chemicals in common commerce, animal toxicity data exists. Such data usually consists of the results of experiments designed to determine lethal dose (ie. LD_{50}, LD_{90} etc.) and experiments designed to determine long term toxicity where small doses are administered in the diet for months to years. Most such data is accrued from rodent experiments. Clearly, there are major difficulties in using animal toxicity data to predict human toxicity. There are numerous well recognized examples of the dramatic non-concordance of such data. Furthermore, the conditions of the usual animal experiments described above rarely mimic the more usual human exposure scenario where moderate but usually sublethal doses are encountered for relatively brief periods.

Likewise the occupational data, while having the advantage of being human, also suffers from the dissimilarity of the "design" with the usual exposure encountered as part of a hazardous materials incident. That is the data generally relates to the prevalence of a particular disease (e.g. cancer) after many years of exposure to relatively low levels of chemical.

Finally, data from prior "accidents" with a chemical are often the most revealing in that the scenario is likely to be similar. Unfortunately little of this data exists, or at least little is retrievable on an acute basis. Very few publications in the public health or medical literature provide systematic data on victims of accidental chemical exposures. Generally this data is not collected in a usable format at the time of the incident and even when the data is collected it is rarely published in an available format. There is an urgent need for the development of reporting data bases of health data from chemical exposure incidents - data bases which could readily be accessed by subsequent health care providers faced with similar exposures.

One proposal which might lead to easier reporting of health effects and which would produce data of great potential value in planning for hazardous materials disasters involves the simple categorization of chemical injuries into the following six categories: 1. no medical care required, 2. field first aid only, 3. emergency department or clinic care needed, 4. hospitalization required, 5. intensive or special care required, 6. death. Such a system, while crude in terms of specific health information, provides precisely the information needed by health planners.

Given a relationship between a chemical and specific human toxic effects, it could be helpful to be able to calculate risk to injury of any degree of exposure. Such calculations are termed risk analysis. As it is unlikely that sufficient human data exist to directly determine this risk over a range of exposures, these estimates must be calculated assuming a specific model of the quantitative dose-response relationship. The model often selected because of its known fit to much human and animal data is the probit model. This model assumes individual thresholds to response - that is, there is a dose below which an individual will not respond with the adverse effect - and that the distribution of these thresholds is normal when plotted against the log of exposure. This model produces a sigmoid shaped dose response curve. Other models have also been proposed and used, particularly for low dose exposure to carcinogens where it is often assumed that no threshold or safe exposure level may exist, although they have also been used to calculate "safe" exposure levels for other chemicals. The primary use of such models has been to predict cancer risk in populations exposed to human carcinogens. It should be remembered that all such models are designed for predictive use in large populations and have a high potential error when used on a small group.

TABLE 1. EXAMPLES OF CHEMICALS CAUSING SPECIFIC ORGAN INJURY

Organ	Chemical	Nature of Damage
1. Skin	mineral acids dioxins hydrocarbons	necrosis acne-like rash irritation
2. Eye	formaldehyde chlorine methyl alcohol	irritation burns blindness
3. Lung	asbestos chlorine organophosphate insecticide	fibrosis/cancer irritation/bronchitis pulmonary edema
4. Liver	carbamate tetrachloride phosphorous	liver cell injury jaundice
5. Intestines	copper carbonate insecticides lead	vomiting diarrhea abdominal pains
6. Kidney	ethylene glycol diquat	kidney blockage kidney cell injury
7. Heart	carbon monoxide phosgene fluoride	irregular rhythm increased heart rate hypotension
8. Central Nervous System	hexachlorophene thallium carbon disulfide	seizures delirium coma
9. Peripheral Nervous System	manganese hexane acrylonitrile	Parkinson-like condition muscle weakness loss of sensation
10. Blood	arsine benzene	anemia low white blood cell count
11. Immune System	dioxin/PCB's	immune deficiency
12. Reproductive System	alcohol lead dibromochloropropane	fetal injuries abortion low sperm counts
13. Musculoskeletal	aluminum fluoride	under mineralization of bone defective dental enamel

II. Mechanisms of Toxic Injury

In a very general way chemicals can affect human tissues in three broad ways: structural damage to the tissue, interference with cell function, or alteration of genetic material within the cell. Any given chemical may act by more than one mechanism. It should also be noted that hazardous materials events may also provoke symptoms in the absence of any demonstrable evidence of injury. Such psychogenic symptoms may be both physical and psychological in nature and may impose a major stress on health resources at the time of a major disaster.

Structural damage to cells is usually the result of direct exposure of the tissue to the chemical at relatively high concentration. Such effects are well exemplified by the tissue destructive effects of strong acids and alkali - capable of causing major injury when dermal,mucosal or ocular tissue are exposed for even brief periods of time. Similar effects may occur in the lung following the inhalation of corrosive gases such as chlorine.

Undoubtedly the most common general mechanism of toxicity involves the effect of chemicals on cellular function. Such effects can occur by a myriad of different routes which may lead to altered cell function, cell death. or cellular alteration. Effects on specific cell types may in turn lead to organ death or dysfunction. Well known examples of such injury would include the effects of chlorinated solvents such as carbon tetrachloride on the liver and the effect of the herbicide paraquat on the lung. Many other well studied toxins have been shown to produce their clinical effect by way of specific changes they may induce within the cell. Chemicals known to be teratogenic - that is those which produce abnormalities in offspring if exposure occurs during fetal development - also work by altering the normal development of early cell types.

A relatively few chemicals are known to alter the genetic material in cells. Such chemicals are said to be mutagenic. Changes in the genetic make-up of cells can lead to abnormalities in offspring. Direct mutagenesis is also thought to be one mechanism by which malignancies are produced. Examples of chemicals in this last category would include the common solvent benzene and benz(a)pyrene. Radiation is also known to be mutagenic.

For some chemicals, toxicity is in part dependent on changes produced in the chemical by the body. That is, the chemical itself may be relatively non-toxic but the body is capable of converting the chemical into a much more potent toxin. This phenomenon is termed metabolic activation. For most chemicals however, the body will convert these chemicals into less toxin and more water soluble products as part of the body's normal elimination processes.

Finally, we need to distinguish between the effects of a chemical following acute and chronic exposures. For many but not all chemicals, chronic (months to years) exposure will lead to some accumulation of the chemical or its metabolic products in body tissues. Some chemicals are eliminated from the body so rapidly that no significant accumulation occurs.

The nature of exposure (acute versus chronic) is an important consideration in assessing toxic potential. For some toxins, particularly those where exposures tend to be low (e.g. environmental exposure to PCB's or dioxins) toxicity may only occur after prolonged exposure resulting in significant body burdens of toxin. For many chemicals the pattern of toxic effects is different following acute and chronic exposures.

III. Clinical Toxicity

Chemicals can enter the body by a variety of routes. The most common routes in hazardous materials exposures are inhalation and dermal absorption. Occasionally such accidents my lead to entry via ingestion, injection injury or even absorption through the eye. Often multiple sites of exposure occur in the same victim. Once into the body, chemicals enter the circulation and reach all organs in the body to varying degrees. Which organs will exhibit significant damage is primarily chemical dependent. Prediction of which organs will be "target" organs is problematic for any chemical and must be extrapolated from chemical similarities to other chemicals whose toxicity is known. To some degree the "target" organs in an individual with a specific exposure are also individual specific. That is, while a specific chemical may be known to produce symptoms of brain, liver and kidney damage in humans, not all individuals, given a specific dose, will respond with the same pattern of injury - some may have evidence of brain damage alone while others may show only evidence of liver damage. The precise reasons for this variability of response are not known.

Inhalation represents the most common route of exposure to hazardous materials. Physical contact with a solid or liquid chemical which might lead to extensive dermal contact or ingestion is generally limited to those in very close proximity to an event. However, the spread of a chemical as a true gas, mist, dust or fog may be quite extensive leading to the potential exposure of large populations located some distance from the initial event. Such exposure may involve both dermal and ocular exposures to the chemical as well as inhalation, although the latter is usually the most significant.

The nature and degree of pulmonary injury from an inhalation exposure depends on a large number of factors including: The chemical(s) involved and their concentrations, particle size if not a true gas, duration of exposure, temperature, respiratory rate and route (oral or nasal) and any pre-existing respiratory disease. Unless overwhelmed or bypassed by oral breathing, the upper respiratory tract is relatively efficient at removing large particles such as fogs and dusts. Smaller particles and true gases, however, may penetrate deep into the respiratory tract leading to more diffuse and generally more severe injury.

Absorption through the skin occurs with most chemicals, although for many it is a relatively slow process. Some chemicals, however, such as lipid soluble solvents may be absorbed quite readily through the skin. It must also be remembered that in may hazardous materials events individuals in close proximity to the site may suffer significant damage to the skin from physical trauma or burns. These injuries may negate the effectiveness of the skin as a barrier and may result in enhanced absorption of chemicals.

Direct ingestion of chemicals is uncommon in hazardous materials events although explosions and splashes may result in modest oral exposures. The possibility exists of large scale exposures via ingestion of domestic water systems which have become contaminated by chemical run-off or ground water leaching caused by spills or releases. While many chemicals may have odors or tastes which will warn of their presence at very low concentrations, others may not. It may be necessary to rely on chemical analysis of suspect water supplies to confirm their freedom from chemical contamination. Fairly modest levels of chemicals in domestic water systems may lead to significant exposure because of relatively large volumes of water to which the average citizen is exposed and because of the high efficiency of absorption which occurs with most chemicals in the gastrointestinal tract.

Finally, an uncommon but potentially devastating route of exposure is the injection injury. Chemical is literally blasted into the tissue as the result of its release under high pressure in close proximity to the victim. Such injuries may result from explosions or ruptures or malfunctions of high pressure equipment. Injection of many chemicals in this manner leads to severe tissue injuries not infrequently resulting ultimately in the loss of the body part.

As mentioned above, chemicals are capable of damaging virtually any organ system in the body. The specific "target areas" will depend on the organs in which a particular chemical concentrates and the sensitivities of the particular tissues in that organ to damage. Not all chemicals damage all tissues. At sufficiently low concentrations, no tissues will be damaged by most chemicals.

Table I provides examples of chemicals known to cause injury to specific body tissues. These are examples and are by no means the only chemicals known to injure these tissues. This sort of information is extremely valuable to health care providers in determining what medical problems need to be anticipated following exposure to chemicals. It may prevent the unnecessary cost of needlessly monitoring organ systems which are not damaged by the chemical in question. In the case of a large disaster with multiple victims it may also alert the medical system as a whole allowing it to anticipate the resources which may be needed. Thus, if the chemical were chlorine gas, it could be anticipated that extensive pulmonary support resources would be needed.

It should also be noted that hazardous materials events may involve several chemicals. There is almost no data available on simultaneous human exposure to multiple chemicals. As a general rule the effects produced will be assumed to be additive, although with some chemical combinations one might anticipate that synergistic effects could occur.

It should also be noted that for large events a distinct risk occurs of secondary exposures of individuals via environmental contamination. This was mentioned above in the context of water pollution, but it may also occur if large land surfaces are contaminated from explosions or toxic clouds. Of particular risk under such circumstances are children who tend to have much greater exposures to soil contamination than most adults.

IV. Prevention of Chemical Injuries

There are four areas which can impact on the outcome of potential chemical injury: measures to minimize exposure, rapid and effective documentation of victims, rapid access to definitive medical care and advance planning.

Minimizing exposure can occur in a number of ways. Perhaps the most important is providing appropriate information for large populations in areas with potential exposure. While evacuations of such populations often would seem to be the appropriate solution this is often not possible or practical within the time contracts imposed by the spread of hazardous materials. For many chemicals a safer alternative is to shelter-in-place such populations by providing information on closing off dwellings or work places until a cloud of toxic material has passed or dissipated. Either of these approaches require the ability to effectively communicate with this population. Minimizing the exposure of initial responders is also important, both to assure their safety as well as to assure the effectiveness of intervention. This includes recognizing the nature of the hazard, providing effective protective gear for those in the danger zone and keeping non-essential personnel in a safe area.

As discussed previously, one of the important variables in determining the amount of chemical which one is exposed to is the duration of exposure. For this reason rapid and effective methods of removing the chemical from those exposed, particularly those with dermal or ocular exposures, can make the difference between minimal or serious injury. Clearly advance preparation and training of responders at all levels together with the availability of appropriate equipment and supplies is necessary for this occur.

Of equal importance is the rapid availability of definitive medical care, usually at a civilian hospital facility. Rapid access of care requires the ready availability of appropriate transport services, usually ambulances with crews trained in the handling of chemically contaminated patients. Hospital facilities must have access to staff trained in basic life support as well as specialty areas, most notably pulmonary medicine. The availability of intensive care services will be crucial for those few percent of victims who require this level of care.

Finally, as noted above, advance planning is crucial if injuries are to be minimized in a hazardous materials event. Planning must involve all participants in the response, particularly those with roles in the health delivery system. It is clear from many documented experiences that if involved units are not individually trained in their roles and not experienced in working together as an integrated response team, that results, in terms of the prevention of morbidity and mortality, will be poor.

V. Summary

It is clear that chemical exposure in the context of hazardous material related events and their secondary environmental contamination have the potential for major impacts on individual and public health.

Optimal response to these events, when they occur, requires knowledge of the toxic effects to be anticipated from these chemicals under the conditions of the event, together with properly trained and equipped response units. Both in the area of current knowledge and in the area of response capability, serious defects presently exist. Future efforts should be directed at improving the collection, organization and dissemination of information gained from hazardous materials events. There is also a serious need for improving integrated response capabilities, both within political jurisdictions and across jurisdictional lines.