Managing the Medical Response to a Major Industrial Accident Involving Uncontrolled Chemical Exposure

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ABSTRACT

Physicians in the community who are called upon to respond to incidents involving uncontrolled chemical exposure are seldom prepared to do so; physicians with special training in occupational and environmental medicine are in short supply and may not be readily available. Prompt medical care and the provision of first aid are driven by the clinical profile of toxicity encountered among the affected patients; there are few "antidotes" or specific treatments in clinical toxicology. Therefore, with certain important exceptions, the provision of medical care is fairly straightforward. However, there is a role for a consultant or advisory physician on the scene. We recommend a simple, three-step approach for physician responders, as follows: Step 1: Evaluate the problem. Guidelines are provided for assessing the likely magnitude of the incident and identifying vulnerable subgroups in the exposed population. Step 2: Contain the problem. Working with emergency response personnel, the physician may assist in limiting the magnitude of the impact and in expediting both prompt medical care and the provision of an authoritative interpretation of the health implications of the incident. Step 3: Evaluate the "survivors", including the large fraction of potentially exposed persons who may or may not have sustained significant toxicity and the even larger population of "worried well" who are seeking reassurance or whose medical condition bears a questionable relationship to exposure. Guidelines on how to do so are presented. Other roles for the physician include occupational health protection for workers involved in emergency response and remediation, support for mental health interventions and debriefing, and documentation of medical signs and symptoms in anticipation of future medicolegal complications.

INTRODUCTION

Incidents involving hazardous substances may take many forms, among them transportation spills, leakage from storage sites, abandoned waste disposal sites, process malfunctions and emissions, and catastrophic plant incidents. The immediate priority is usually to bring the incident under control. The implications of the incident for human health are always a high priority, however. There is seldom a physician trained in toxicology or occupational and environmental medicine immediately on hand when these events occur. However, the risks to human health are always a major concern.

The preparation of emergency response personnel has outstripped the education of physicians on matters involving hazardous substances. Most physicians are not trained or prepared to deal with incidents involving hazardous substances. Indeed, most physicians are not trained to deal with toxic substances and related health issues, except for medication side effects and common poisonings seen in inquisitive children and suicide attempts. This presentation outlines an approach to the medical management of an incident or the identification of a hazardous waste disposal site.

In most situations there are immediate and pressing issues to be resolved that require medical expertise. These may include the following:

- initial evaluation of the health risks for purposes of triage of exposed persons
- determination of appropriate treatment for exposed persons who are injured or ill
- medical advisories to be released for the protection of nearby residents
- decisions to evacuate the area based on health risks
- measures to protect vulnerable populations (such as the aged, the very young, women in pregnancy, the chronically ill)
- exceptional risks to emergency response personnel
- risks to clean-up and remediation workers
- documenting health risk for subsequent civil litigation and for insurance purposes
- identifying potential medical evidence for future legal action in suspected criminal cases

The following is an approach to the immediate medical response to an incident involving hazardous substances, and a simple three-step process for physicians who are involved. The process was developed during a simulated emergency and has been described in several previous publications. It has been applied by us at the University of Alberta in our own response to incidents involving hazardous substances. We also developed a continuing medical education program based on this approach, which is available for the training of physicians through the Association of Occupational and Environmental Clinics (1010 Vermont Ave., NW, #513, Washington DC 20005 USA); it is entitled "Living on the Chemical Edge." Some of the text used here is taken from this program, by permission.

If there is a possibility that physicians along a transportation corridor or in a given locale may be involved in an incident or may deal with residents affected by hazardous waste, it might be prudent to share a photocopy of this report with them in advance or to arrange to borrow the above-mentioned program.

HAZARDOUS SUBSTANCES AND THE EVALUATION OF TOXICITY

Hazardous substances are compounds and mixtures that pose a threat to health and property because of their toxicity, flammability, explosive potential, radiation, or other dangerous properties. Public attention tends to focus on carcinogens, industrial wastes, pesticides, and radiation hazards. However, innumerable compounds that do not fall into these categories can pose a threat to the public's safety and health.

Gasoline, for example, can explode with the destructive force of gunpowder. Although we are concentrating here on toxic exposures, we should not forget the

substantial problems of safety that appear in many situations. Fires and explosions also generate their own toxic hazards depending on the chemicals that were initially present. However, even relatively inert gases, such as nitrogen or the freons, can kill by asphyxiation when they accumulate in an enclosed space.

Before discussing the role of the physician in dealing with all this, let us spend a few minutes discussing the toxicological issues.

Although incidents involving hazardous substances take many forms and may be highly individual, the great majority seem to involve a relatively narrow range of hazardous substances, which include: solvents, paints and coatings, metal solutions, PCBs, pesticides, and acids and alkalis. It is worth remembering that skin rashes are the most common health effects of exposure to all of these chemicals.

Solvents, particularly chlorinated compounds, are environmentally persistent, meaning that they tend to remain in the ground or water as contaminants for many years and are concentrated in the bodies of fish, birds, and other wildlife. Many solvents are toxic to human beings in relatively high concentrations and some are known or suspected carcinogens. In practice, these compounds are usually of less direct concern with respect to human health than for environmental pollution. The most toxic solvents have been withdrawn from industry for some years but old waste sites may contain significant amounts of benzene and trichlorethylene. Some of these same compounds, such as benzene and toluene, are also present as combustion products when organic material such as tires are burned. Paints and coatings are of concern primarily because of the solvents and metals they may contain.

Heavy metals are also environmentally persistent and may be highly toxic. The chances of significant exposure occurring as a result of exposure in a hazardous waste site are low but this could happen, especially to a young child who is playing in dirt or with groundwater contamination. A particular problem is found in areas contaminated by smelter or lead battery reprocessing operations, where arsenic or lead in the soil may reach high levels.

Chlorinated cyclic hydrocarbons, and particularly the PCBs, are very damaging environmentally because they persist for long periods and are consumed and accumulated by wildlife. Despite their fearsome reputation in the laboratory, however, these compounds are not highly toxic to humans. All four of the chemicals shown are capable of causing an unusual and persistent skin rash called "chloracne" that appears on the face and neck of people who are heavily exposed. These compounds are known to cause cancer in animals. (Pentachlorophenol is not yet confirmed). However, this does not mean that they affect humans in the same way. Although some of these compounds are among the most potent carcinogens identified in laboratory studies of animals (other than primates), they do not seem to present nearly the same risk to humans. Numerous studies have now been conducted without demonstrating a clear association between exposure to these compounds and cancer in humans. We humans appear to be more resistant to the effects of these compounds than other species. If a person is exposed to PCBs, pentachlorophenol, or even to dioxins and furans, they are *not* doomed to cancer because of their exposure and may show no effects at all. Even so, these are dangerous compounds to the environment and must be controlled for ecological reasons. We still do not know many of their more subtle

effects on humans and it is only prudent that we minimize exposure to humans as well.

Pesticides are particularly dangerous in hazardous waste, especially the relatively toxic class known as the organophosphates. Fires involving pesticide storage areas are a particularly dangerous situation, as the pesticides may be converted into even more highly toxic combustion products and substantial amounts of environmentally damaging dioxins and furans may be generated.

Strong acids and strong alkali are commonly found at waste sites and are dangerous if there is a possibility of direct contact or inhalation of fumes. They may cause serious skin and eye burns on contact. Some acids may generate clouds of fumes which may cause lung injury. If mixed together, the acids and alkali may generate intense, possibly explosive heat and substantial dangerous fumes. Two acids that are particularly dangerous are nitric acid and hydrofluoric acid. Nitric acid releases nitrogen dioxide, which may cause pulmonary edema and bronchial irritation. Hydrofluoric acid is used for etching in the electronics industry and is exceedingly dangerous when inhaled. On contact with skin or eyes, it causes deeply penetrating burns.

Cyanide is present in some situations, especially gold plating solutions. When inhaled, cyanide fumes from the solution are highly toxic. Cyanide can be released by mixing the plating solution with a strong acid, such as those often found at hazardous waste sites.

ROLE OF THE PHYSICIAN

A true hazardous substances emergency is best managed by a specialist with training in toxicology, epidemiology, and public health. In Canada, these physicians are usually specialists in occupational and environmental medicine or community medicine. Such specialists are in short supply, however, and may not be on the scene when an incident occurs. With regionalization of health care services, the first contact is likely to be an environmental health officer who will probably request assistance from a medical officer of health, who may or may not have relevant expertise. Some regions do not have medical officers of health and environmental health services may have no physician in a position of authority. In practice, therefore, almost any practitioner may be presented with a problem related to toxic exposures. In cooperation with public safety and public health activities, a family practitioner in rural or remote areas may have to serve as consultant on health without preparation.

In discussing the role of a physician in all this, we must consider four main areas:

1) What the physician does in an emergency,
2) How the physician deals with cases of suspected toxicity,
3) How the physician deals with the "worried well" who fear toxicity but are probably unaffected, and
4) How the physician deals with the workers involved in clean-up operations.

Here is a checklist of basic questions to help get started. A careful, methodical approach is just as important as a detailed knowledge of the hazards involved.

Three basic steps are generally followed. Most of them are common sense. The first step is evaluation. The second is to contain the problem. The third, and the main step where the physician is involved, is management of the health effects.

Step 1: Evaluate the Problem

The major role of the physician at this step is as an advisor and resource for technical information. To perform this role, the physician needs the most accurate possible information on the following:

1. What hazardous substances are involved?
2. What are their toxic and safety hazards?
3. How many people have now been exposed and how many may be exposed in the near future?
4. Among these people, are there any who may be at exceptionally great risk?

This information may change constantly during a real episode. In a typical incident, there are innumerable false reports, doubts, and updates. The physician involved must be prepared to be flexible.

Correct identification of the substances involved is essential. Labels on drums may be misleading because these drums are often recycled. Samples should be taken by an environmental health specialist or industrial hygienist who wear suitable personal protective equipment.

Unless there is a compelling reason to act, such as a fire or a rapid leak, it is usually wise to let the material rest where it is until the material is identified and suitable precautions can be taken. If an emergency forces action before the material is identified, the only prudent move is to assume the worst unless one has evidence that the material is not highly toxic. Unidentified materials usually turn out to be fairly benign. However, until they are identified they often cause general great concern and anxiety by requiring the use of full protective gear by emergency response personnel.

Once the identity of a material is known, the hazard potential must be determined. There are a number of sources of information on the toxicology and safety hazard of common industrial and commercial chemicals. Unfortunately, the MSDS is seldom very helpful to physicians in managing these cases. MSDSs usually give reasonable information on the safety hazard of chemical formulations, but they are almost always incomplete in their descriptions of the compounds' toxic effects. They are usually weak or missing information on chronic effects. Many chemical formulations are proprietary mixtures and their formulations are considered trade secrets. The MSDS may not identify specific chemicals or their proportions. As well, the MSDS collection in the files of many companies are incomplete, and not all pertinent MSDSs may be available on short notice.

Other sources of information include many that are familiar to physicians for clinical information: Medical libraries are obvious. Law libraries, however, also often have works on toxicology available. Both usually carry the standard reference works in toxicology and can order computerized literature searches for users. Many familiar medical texts such as Goodman and Gilman have pertinent information on toxic

exposures. Certain books are particularly useful to have on hand and the ones that are probably most helpful in an emergency are these:

Ellenhorn and Barceloux. *Medical Toxicology*. This is an excellent, comprehensive reference book.

Proctor and Hughes. *Chemical Hazards of the Workplace*. This source is rather dated now but remains the single most useful first step for looking up the effects of chemicals.

Sax. *Dangerous Properties of Industrial Materials*. This source is a superb, complete reference with chapters on practical issues as well as a profile of numerous chemicals; it is expensive, however.

There are also usually local resources that can provide advice and knowledgeable consultation. These include: regional academic centres, the membership of organizations (such as the Occupational and Environmental Medical Association of Canada), or professionals who are associated with local industries and are familiar with the chemical. If local resources are not sufficient, there are national "hot-line" telephone numbers. We are not aware of on-line services that serve this purpose as yet, but eventually this capability will almost certainly be developed.

The next step in determining the hazard presented by the incident is to find out what is happening to the toxic material at the site. Once spilled, the waste seeps into the ground, through the soil, and often into groundwater. The possible migration of the waste materials is an important part of the initial assessment. A clear idea of how the chemical will spread is very important in determining who is likely to become exposed. For example:

1) If the incident is a gas leak, how many homes are downwind?
2) If the incident involves a liquid waste seeping into the ground, how many families draw their water from local wells?
3) If the liquid waste is flowing downhill as surface runoff, perhaps into a storm drain or stream, where does the water go?
4) How many children in the area might play in or explore the site?
5) Will the prevailing winds carry a plume away from or toward residents?
6) If groundwater is contaminated, is drinking water or irrigation water likely to be fouled?
7) If it rains or if snow melts, will surface runoff carry the waste off site?

Water must sometimes be supplied to residents, when drinking water supplies are contaminated.

Not everyone in the community will actually be exposed, of course, and for purposes of planning a medical response, it is important to consider the characteristics of the persons who may actually come into contact with the material.

Children may develop skin rashes from direct contact: fumes may be merely

annoying to the young and healthy, but could be troublesome or life-threatening to the elderly, those who have cardiovascular or pulmonary diseases, to infants, or to asthmatics. Pregnant women require special attention to protect mother and fetus. Knowledge of the community at risk allows health authorities to warn susceptible individuals to take protective measures or to leave the area.

Step 2: Contain the Problem

The next step is to establish control over the situation in order to minimize the exposure potential. This requires teamwork between police, fire, and public health authorities and obviously varies with the nature of the incident. The physician is still serving as an advisor in this step.

In more complex situations, coordination among and with local authorities is essential. Fire departments are best equipped to handle safety hazards but often need advice and assistance in dealing with toxic materials. The most difficult situations, such as fires involving multiple toxic substances, known and unknown, pose serious threats to public safety personnel and may require on-site medical presence.

In extreme situations, evacuation may be unavoidable. The mental health consequences of evacuation are great and this extreme step should never be taken without good reason. Large-scale population evacuations carry a high cost in stress and safety problems, as well as the potential for violence.

An important aspect of containing the problem is to prevent public overreaction. An incident like this provokes rumors and misinformation that must be set straight in order to avoid panic or misguided interference in public safety measures. Early establishment of a rumor control committee, a hotline, and good working relations with the media can be very valuable. It is particularly important to funnel all public information, whenever possible, through a single spokesperson. Otherwise slight differences of opinion, interpretation, and understanding may appear as confusion, uncertainty, and rivalry among responsible authorities.

Step 3: Manage the Health Effects

Most clinicians feel uncertain and overwhelmed when called on to deal with complex toxic exposures. Although these cases are admittedly complex, there are certain guidelines that can be followed.

There are two separate problems that the clinician faces: evaluation of persons who probably were exposed and evaluation of the "worried well" who are concerned about the possibility of exposure and need to be reassured.

Medical emergencies involving hazardous substances are less common than situations in which a person believes his or herself to have been exposed to a toxic substance and seeks a medical evaluation. When the substance is known, an appropriate medical evaluation can be derived. When the substance is not known or involves a complex mixture, the appropriate medical evaluation may be difficult to determine.

Many incidents involve multiple exposures or substances that have multiple effects. It is good practice to provide a basic comprehensive evaluation in all cases. When a patient presents with a specific clinical complaint it is important not to focus the

evaluation too narrowly because important findings may be missed. We recommend a basic battery of tests and the collection of information that is useful in interpreting the results. We have adopted the screening test battery outlined in Table 1, provided below, as a guide for physicians who are not specially trained in this field.

An important role for the medical officer is the protection of workers engaged in cleanup and control activities at the site. The U.S. Environmental Protection Agency has developed a recommended evaluation for clean-up workers, which looks much like the evaluation for affected residents mentioned previously. The physician should inquire about the availability of suitable protective gear, decontamination procedures, and the presence of security and emergency services. In speaking with the workers, one should emphasize the importance of not smoking and eating on the site, checking oxygen levels before entering any confined space, use of the buddy system (always working with a companion with access to rescue equipment), and leaving contaminated clothes at the site.

It is much easier to deal with well-defined situations in which the nature of the exposure is known or the clinical presentation is clear. Situations in which there is exposure to a single agent are simplest to manage. The appropriate medical response then depends on accurate toxicologic information.

In a complex or obscure situation where the identity of the exposure is unknown or in doubt, the clinician should consider the possibility of acute effects involving those organ systems most commonly involved in toxic injury: the respiratory, renal, hepatic, dermatologic, and nervous organ systems. We provide a reasonable approach for a physician without specialized training in this field to take when the agent is unknown. (Table 1 and Table 2) It should be performed two or three days after the suspected exposure, after the effects have had time to develop. When new information regarding the nature of the exposure becomes available, the clinician can then modify the examination accordingly. A guide to the interpretation of these screening tests is provided in Table 2.

CONSEQUENCES FOR THE COMMUNITY

When an incident or the suspicion of trouble with a hazardous waste site emerges, communities may be devastated. A particular concern is fear of cancer. This fear has effects on the community that may be far worse than the direct effects of the waste site. There is often considerable pressure to document the presence of an excessive rate of cancer by conducting epidemiological studies. Epidemiological studies are very valuable research and public health tools but they have their limitations. They are often misunderstood by the public. They may not answer the question and often raise new extraneous or secondary issues that will need to be addressed. Epidemiological studies should certainly be considered when they are indicated on research and public health grounds but they are not good as nonspecific or general responses to community concerns.

A major issue in dealing with incidents involving hazardous substances is the psychological effect of the incident upon the residents. The effect can be devastating and long-lasting. The emphasis on management should be on mental health interventions and recognition.

The response of residents to incidents involving hazardous substances and other actual or preceived "disasters" caused by human activity show distinct differences from the response following natural disasters. A manmade disaster, which is often referred to in the relevant literature as a "technological" incident or disaster, has certain characteristics that cause it to be perceived differently from a natural disaster.

Natural disasters are usually perceived as "clean" and are considered "acts of God". Technological disasters, on the other hand, are usually perceived as "dirty" or contaminated, particularly if they involve chemical substances. There is usually some anxiety that the survivors will carry some risk for the rest of their lives because of chemical contamination and exposure. There are also usually legal questions of liability, eligibility for compensation, failure of duty on the part of those responsible to warn the victims, and responsibility for the incident in a legal and moral sense.

In the case of natural disasters, it is common for the community to rally around the victims in an outpouring of support and sympathy. In the case of technological disasters, there is often considerable reluctance by outsiders to get involved. This may reflect fear of involvement in legal complications or a nagging doubt, particularly in the case of industrial accidents, over who was at fault. Often, neighbors wonder to what extent the survivors may be exploiting opportunities for compensation or secondary gain. The community may even feel threatened by the survivors if a major employer is involved and jobs could be lost. By contrast, the community response is usually nonjudgemental and is often very generous in the case of natural disasters.

People who live through such an incident often experience strong emotions that they find difficult to communicate to others. These emotions often continue long after the incident. The conflict and psychological trauma are not unlike those experienced by veterans of combat or survivors of torture, although obviously less severe for most. The psychological manifestations are often those of the "posttraummatic stress" syndrome.

The most common symptoms experienced by people who live through these incidents are repeated recollections that may intrude into their thoughts. Often these "survivors" experience a sense of fatigue and malaise. They have no energy and have difficulty concentrating. They may have disturbed sleep with recurrent dreams of disaster. They often shows signs of depression. They may become interested in health foods and alternative approaches to medicine in their search for answers medicine cannot give them.

After experiencing a disaster of substantial magnitude, most people cope with it emotionally by talking about it and many cope by attending counselling and therapy sessions. A great many deny their symptoms and never seek help.

There has been several attempts to design an appropriate mental health intervention for survivors of technological disasters. The best one to date was developed in Kansas City in the aftermath of an incident that involved the collapse of a hotel bridge. This event resulted in particularly gruesome deaths among the individual on the bridge platform and those immediately under it. This tragedy was dealt with by the immediate organization of support groups and the intervention of professional mental health and social service personnel. The professionals were trained to provide services on short notice by specialists in disaster mental health management. These mental health services were accompanied by an urgent media campaign. The

consistent message delivered by the campaign was to "legitimize" reactions to the disaster, to let victims know that their symptoms and reactions were a normal response to a highly abnormal situation, to encourage them to share their feelings with others, and to give them encouragement to seek professional help, if they felt they needed it.

Table 1. Recommended medical screening evaluation for persons possibly exposed to mixtures or unknown toxic substances.

1. Complete medical history, emphasizing the following:

- current health problems
- current medication
- skin disorders, acute and chronic
- respiratory disorders (e.g. asthma)
- most recent alcohol consumption, timing and amount
- liver disease, acute and chronic
- kidney disease, acute and chronic
- cancer
- pregnancy

2. Complete physical examination, emphasizing the following:

- skin (look for new rashes)
- lungs (evidence of new wheezing, bronchospasm)
- liver (evidence of chemical hepatitis)
- central nervous system (neurotoxicity)
- peripheral nervous system (establish baseline for follow-up)

3. Laboratory studies:

- urinalysis
- serum creatinine (to establish renal function)
- liver function tests: ALT, bilirubin (evidence of chemical hepatitis)
- pulmonary function tests
- blood cholinesterase (if acute exposure to organophsophate pesticides is a possibility)

Tests should be performed on second or third day after putative exposure.

Table 2. Interpretation of recommended medical screening evaluation for persons possibly exposed to mixtures or unknown toxic substances.

Clinical Problem	Relevant Test	Follow-up Test	Other Causes
Dermatitis	Physical exam	Physical exam Patch testing	Any cause of rash
Respiratory disorders	Pulmonary function tests Chest film if symptoms	Pulmonary function tests Methacholine challenge Chest film if indicated	Acute and chronic respiratory disease
Liver toxicity	Liver function tests	Liver function tests	Hepatitis, alcohol consumption
Kidney toxicity	Urinalysis Creatinine	Depends on findings	Chronic or acute kidney disease
Future cancer risk	None	None	Many
Reproductive health effects	Variable	Variable Monitor pregnancy	Many
Pesticide toxicity, acute	Cholinesterase	Cholinesterase	Other sources of exposure to organophosphate or carbamate pesticides

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Key Words

hazardous substances

toxicology

medical evaluation

medical monitoring

mental health interventions

disaster preparedness

The Medical Implications of a Major Incident with a Large Number of Victims Suffering Severe Burns

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