



***Managing
Hazardous
Materials
Incidents***

Volume III
(revised)

**Medical
Management
Guidelines for
Acute Chemical
Exposures**

**U.S. Department Of Health And Human Services
Public Health Service
Agency for Toxic Substances and Disease Registry**

The state of knowledge regarding the treatment of patients potentially exposed to hazardous substances in the environment is constantly evolving and is often uncertain. In this document, the Agency for Toxic Substances and Disease Registry (ATSDR) has made diligent effort to ensure the accuracy and currency of the information presented but makes no claim that the document comprehensively addresses all possible situations related to this topic. This document is intended as an additional resource for physicians and other health professionals in assessing the condition and managing the treatment of patients potentially exposed to hazardous substances. It is not, however, a substitute for the professional judgment of a health care provider and must be interpreted in light of specific information regarding the patient available to such a professional and in conjunction with other sources of authority.

**Agency for Toxic Substances and Disease Registry
2000**

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Acronyms and Abbreviations

AAPCC	American Association of Poison Control Centers
ABG	arterial blood gases
ABS	acrylonitrile/butadiene/styrene
ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ALS	advanced life support
AOEC	Association of Occupational and Environmental Clinics
ARDS	acute respiratory distress syndrome
ATSDR	Agency for Toxic Substances and Disease Registry
BAL	British anti-Lewisite (dimercaprol)
BUN	blood urea nitrogen
C	Celsius
CDC	Centers for Disease Control and Prevention
CAS	Chemical Abstract Service
CBC	complete blood count
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CNS	central nervous system
CPC	chemical protective clothing
CPK	creatine phosphokinase
DC	direct current
DHHS	Department of Health and Human Services
dL	deciliter
DMSA	2,3-dimercaptosuccinic acid
DNA	deoxyribonucleic acid
DOT	Department of Transportation
ECG	electrocardiogram
ED	emergency department
EEG	electroencephalogram
EMS	emergency medical services
EMSA	Emergency Medical Services Authority
EPA	Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
F	Fahrenheit
g	gram
GABA	gamma aminobutyric acid
GAO	General Accounting Office
GI	gastrointestinal
G6PD	glucose-6-phosphate dehydrogenase
HAZMAT	hazardous material
HCl	hydrochloric acid
HClO	hypochlorous acid
HSDB	Hazardous Substances Data Bank

IARC	International Agency for Research on Cancer
IDLH	immediately dangerous to life and health
IRIS	Integrated Risk Information System
i.v.	intravenous
kg	kilogram
L	liter
m	meter
mEq	milliequivalent
mg	milligram
mL	milliliter
mm Hg	millimeters of mercury
m ³	cubic meters
MSDS	Material Safety Data Sheet
MSHA	Mine Safety and Health Administration
MTBE	methyl- <i>t</i> -butyl ether
MW	molecular weight
NAC	N-acetylcysteine
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NO	nitric oxide
NPIRS	National Pesticides Information Retrieval System
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
PAM	pralidoxime chloride
PEG	polyethylene glycol
PEL	permissible exposure limit
PhAC	S-phenyl-N-acetyl cysteine
Po ₂	partial pressure of oxygen
ppm	parts per million
PVC	polyvinyl chloride
RADS	reactive airways dysfunction syndrome
RBC	red blood cell
SARA	Superfund Amendments and Reauthorization Act
SCBA	self-contained breathing apparatus
STEL	short-term exposure limit
TBA	<i>t</i> -butyl alcohol
TOCP	tri- <i>o</i> -cresyl phosphate
TSCA	Toxic Substances Control Act
TWA	time-weighted average
TERIS	Teratogen Information Service
UN	United Nations
UV	ultraviolet
WHO	World Health Organization

Preface

The Agency for Toxic Substances and Disease Registry (ATSDR) is an agency of the Public Health Service in the U.S. Department of Health and Human Services (DHHS). ATSDR was created by the U.S. Congress through the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The Agency's responsibilities were markedly increased through the Superfund Amendments and Reauthorization Act of 1986 (SARA). The mission of ATSDR is to prevent or mitigate adverse human health effects and diminished quality of life resulting from exposure to hazardous substances in the environment. In pursuit of this mission, ATSDR provides educational and referral resources to health care providers who are responsible for chemically exposed patients.

The *Medical Management Guidelines for Acute Chemical Exposures (Guidelines)* is designed to assist emergency department physicians. It is the third volume in a 3-volume series provided by ATSDR. The Guidelines contain 40 chemical-specific protocols that provide recommendations for the on-scene (prehospital) and hospital (ED) medical management of patients exposed during a hazardous materials (HAZMAT) incident. Other rescue personnel, such as first responders, emergency medical technicians, and public health officials, will also find the information useful, but because of the focus of the protocols, these professions are encouraged to rely on other sources and training in their primary field for more definitive and complete guidance.

Each chemical protocol is divided into five sections.

- (1) **Description:** Contains synonyms, appearance, routes of exposure; potential for secondary contamination, sources/uses, physical properties, and exposure standards.
- (2) **Health Effects:** Contains organ systems affected by acute exposure, potential sequelae, and effects of chronic exposure.
- (3) **Prehospital Management:** Contains personal protection, decontamination, support, triage, and transportation. Organized by Hot Zone, Decontamination Zone, and Support Zone.
- (4) **Emergency Department Management:** Contains specific medical procedures to treat the exposed patient, and patient disposition. Organized by Decontamination Area and Critical Care Area.
- (5) **Patient Information Sheet:** Contains information on exposure, potential effects, and follow-up instructions for the victims of a HAZMAT incident.

The *Introduction* to this volume provides important background information and a brief overview of the activities at a HAZMAT incident. For more information on managing HAZMAT activities, consult Volumes I and II, *Emergency Medical Services: A Planning Guide for the Management of Contaminated Patients*, and *Hospital Emergency Department: A Planning Guide for the Management of Contaminated Patients*, respectively. The *Introduction* also describes the use, rationale, and limitations of the data contained in each section of a chemical protocol. It is written in the format of an individual protocol. The *Prehospital Management* and *Emergency Department Management* sections of the *Introduction* begin with the recommendations from the *Unidentified Chemical* protocol. The recommendations are followed by the rationale for the procedures suggested. The reader is urged to complete the *Introduction* before attempting to use the individual protocols.

Appendices I through IV contain resources for the emergency department physician seeking consultation in treating chemically exposed patients: AAPCC-Certified Regional Poison Control Centers; Association of Occupational and Environmental Health Clinics; State Health Officials; and private, university, and government consultants are listed. In addition, the *Guidelines* contains a glossary of chemical and medical terminology.

Acknowledgments

This document was first published in 1992 and updated in 2000. ATSDR wishes to thank all those who participated in making this a useful guidance document.

This project was directed by Scott V. Wright, ATSDR. For the 2000 version, Lisa Ingerman, Ph.D., of Syracuse Research Corporation (SRC) was the project manager, and A. Rosa MacDonald, Ph.D., Fernando Lladós, Ph.D., and Susan Little, Ph.D., of SRC were contributing scientists (under ATSDR contract No. 205-1999-00024).

The major contributors to the original (1992) *Medical Management Guidelines for Acute Chemical Exposures* were Jonathan Borak, MD, Kent R. Olson, MD, and Virginia Sublet, PhD.

The following experts served as peer reviewers for the original 1992 document and the 2000 update:

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Introduction

This *Introduction*, which is in the same format as the individual protocols, describes the use and limitations of the information presented. The *Prehospital and Emergency Department* sections incorporate the *Unidentified Chemical* protocol as an example. The *Introduction* is key to the appropriate use of the protocols. Even trained and experienced responders are urged to read it before using the individual protocols in an emergency situation.

Use of trade names is for identification only and does not imply endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

General Information Section
Chemical Name (Chemical Formula)
CAS Number; UN Number

Common synonyms

- **Potential for secondary contamination**
- **Common form and important characteristics such as odor and flammability**
- **Routes of exposure and potential for absorption**

Secondary Contamination

Primary contamination refers to direct contact of the victim with the hazardous material. Secondary contamination refers to the transfer of material from the victim to personnel or equipment. The potential for secondary contamination has implications for decontamination and triage of victims and for the protection of rescue and health care personnel. Immediate victim decontamination is recommended for materials that pose risks of secondary contamination; this eliminates both the potential for rescuer contamination and further exposure to the victim.

A substance poses a risk of secondary contamination if it is both toxic and likely to be carried on the clothing, skin, or hair of victims in sufficient quantities to threaten other personnel. Substances that present the most serious risks of secondary contamination include the following:

- highly toxic liquids and solids or finely divided solids (e.g., organophosphate pesticides)
- radioactive liquids and dusts
- certain biologic agents (e.g., harmful viruses or bacteria)

Every effort must be made to decontaminate contaminated victims before they are transported to a medical care facility.

Examples of substances with little or no risk of secondary contamination include the following:

- gases (e.g., carbon monoxide, amine)
- vapors (unless they condense to a liquid state on clothing or skin)
- substances with no serious toxicity or skin absorption (e.g., propylene glycol, motor oil)

Note that although several of the substances listed above are highly toxic (e.g., arsine, carbon monoxide), they do not pose

risks of secondary contamination because these chemicals will not contaminate the victim; therefore, they cannot secondarily contaminate rescuers.

Secondary contamination also may be a risk in cases of ingestion. Ingested materials may react with stomach acid to produce noxious gases, which can pose risks to both the victim and rescuers. Vomitus may off-gas the hazardous material or a reaction product. Toxic vomitus should be quickly isolated in closed containers.

Previously published documents on hazardous materials have recommended zipping patients into body bags to minimize the transfer of chemical from patient to rescuer. This technique is not completely effective for preventing rescuer exposure, and it may pose a significant risk of increased dermal absorption to victims. Body bags are not recommended as an alternative to thorough decontamination.

Description

This section summarizes the color, odor, and physical state (solid, liquid, or gas) of the chemical at room temperature. Methods of shipment or storage and the physical hazards associated with the chemical are also described.

Routes of Exposure

The most likely routes of exposure--inhalation, direct contact with the skin or eyes, and ingestion--are described. For each route of exposure, the risk of injury depends on the toxicity of the chemical involved, the concentration of the material, and the duration of contact.

Inhalation

Inhalation is the most common route of exposure to gases and vapors. Liquids and solids may also be inhaled when they are finely divided mists, aerosols, fumes, or dusts. Highly water-soluble gases and vapors and larger mist or dust particles (greater than 10 microns in diameter) generally are deposited in the upper airways. Less soluble gases and vapors and smaller particles can be inhaled more deeply into the respiratory tract. Usually, highly water-soluble materials rapidly produce symptoms of upper-airway irritation, whereas less soluble materials may produce delayed symptoms in the lower airways. Inhaled substances may be absorbed into systemic circulation, causing toxicity to various organ systems. When available, information is provided on odor threshold, warning properties, and symptoms to be expected at specific exposure levels.

Skin/Eye Contact

Skin and eye contact can occur by exposure to solids, liquids, or gases. Corrosive agents cause direct damage to tissues by various

mechanisms including low or high pH, chemical reaction with surface tissue, removal of normal skin fats (defatting), or removal of moisture (desiccant effect). Some chemicals absorbed through the skin and eyes can produce systemic toxicity. Absorption, and therefore toxicity, is more likely to occur when the normal skin barrier is disrupted (e.g., chemical burn, cut, or abrasion) or when the chemical is highly fat-soluble (e.g., organophosphate and organochlorine pesticides).

Ingestion

Ingestion is not a common route of exposure in most hazardous materials (HAZMAT) incidents, although it is common in suicide attempts. Ingestion of corrosive agents can cause severe burns to the mouth, throat, esophagus, and stomach. Ingested chemicals may also be aspirated into the lungs, especially after vomiting, causing chemical pneumonitis. Ingested chemicals may react with stomach acid, creating products that are toxic to the patient, and potentially, the health care provider (e.g., hydrogen cyanide from ingested cyanide salts).

Sources/Uses

This section describes the chemical's most common uses and the methods of production.

Standards and Guidelines

Government agencies and professional organizations have established standards and guidelines for hazardous chemical exposures. The standards and guidelines address both acute and chronic exposures.

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) is a regulatory limit established to avoid adverse health effects from exposure. PELs are time-weighted-average (TWA) air concentrations. In most cases, a healthy, working adult can be exposed to a chemical at the PEL for an 8-hour workday and a 40-hour workweek and suffer no adverse health effects. If the measured air concentration at a HAZMAT incident is less than the PEL and the exposure is short-term, persons at the scene are probably not at serious risk. The OSHA "skin" designation indicates the likelihood of dermal absorption.

The OSHA ceiling is an instantaneous concentration that must not be exceeded any time. If instantaneous monitoring is not feasible, the ceiling is normally assessed as a 15-minute TWA concentration.

The OSHA short-term exposure limit (STEL) is a 15-minute (unless otherwise noted) TWA concentration that should not be

exceeded at any time, even if the 8-hour TWA concentration is below the PEL.

The National Institute for Occupational Safety and Health (NIOSH) recommends workplace exposure guidelines. The NIOSH immediately dangerous to life or health (IDLH) level represents the maximum chemical concentration from which one could escape within 30 minutes without a respirator and without experiencing any escape-impairing (e.g., severe eye irritation) or irreversible health effects.

The American Industrial Hygiene Association (AIHA) Emergency Response Planning Guidelines (ERPG) state concentrations at which one might reasonably anticipate observing adverse effects from exposure to specific substances. Unlike occupational exposure standards, ERPG levels are applicable to the general public, including children and the elderly. The three ERPG levels vary with the health effects expected with exposure (transient symptoms, ability impairment, and life-threatening) and apply to practically all persons. The table in the Properties section includes only ERPG-2—the exposure level that could impair a person's ability to take protective action.

ERPG levels are defined as follows:

ERPG-1 is the maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing symptoms other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

ERPG-2 is the maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

Physical Properties

Description: Physical state and useful characteristics of the chemical at room temperature are presented.

Warning properties: Odor and irritation are the primary determinants of exposure awareness. When available, an objective description of odor (e.g., garlic-like) and the lowest air

concentration that can be detected (i.e., odor threshold) is provided. For chemicals with an odor threshold below the toxic air concentration, odor may provide an adequate warning of dangerous exposure conditions. However, a chemical is considered to have inadequate warning properties if it has no detectable odor at toxic air concentrations, has an odor that is not reliably detected because of olfactory fatigue, or does not cause irritation.

Molecular weight (MW) is the sum of the weights of the atoms in a molecule. Molecular weight is provided in daltons, a unit that is based on the mass of oxygen-16. Molecular weight can be used to convert measurements of air concentrations of chemicals from parts per million (ppm) to milligrams per cubic meter (mg/m³) using the following equation:

$$\text{mg/m}^3 = (\text{ppm} \times \text{MW}) / 22.4 \text{ L/mole}$$

(1 mole of gas occupies 22.4 L at standard temperature and pressure).

Boiling point of a liquid is the temperature at which its vapor pressure is equal to the atmospheric pressure. A boiling point at or below room temperature means that the chemical is in the gaseous state at room temperature.

Freezing point is the temperature at which a chemical's solid phase is in equilibrium with the liquid phase. Freezing point and melting point are equal in numeric value. The term "freezing point" refers to the temperature at which a liquid forms a solid; "melting point" refers to the temperature at which a solid forms a liquid.

Specific gravity is the ratio of the density of a liquid to the density of a reference material (usually water). A specific gravity less than 1 indicates that the substance will float on water; a specific gravity greater than 1 indicates that the substance will sink in water.

Vapor pressure is the pressure (expressed in millimeters of mercury [mm Hg]) of a vapor in equilibrium with its liquid or solid form at a given temperature. The higher the vapor pressure, the greater the amount of chemical existing in the vapor phase. A vapor pressure greater than 760 mm Hg at room temperature indicates that the chemical exists as a gas.

Gas density is the ratio of the density (weight per volume) of a substance (at a given temperature) to the density of air (at that temperature). A gas density greater than 1 indicates that the vapor or gas is heavier than air. A gas heavier than air may collect in

low-lying areas where it can displace air, creating an oxygen-deficient atmosphere.

Water solubility indicates the degree to which a substance dissolves in water at a specific temperature. Water solubility is measured in weight of substance per volume of water (e.g., g/100 ml or %). Water solubility may indicate the effectiveness of water in decontamination. A substance that is water soluble is likely to be removed from the skin and hair with a plain water wash. Substances that are poorly water soluble may require the use of soap.

Flammability is the ease with which a material will ignite. Flammable chemicals have flash points below 100 °F; combustible chemicals have flashpoints between 100 °F and 200°F; and nonflammable chemicals have flashpoints above 200 °F.

Flammable range (lower explosive limit to upper explosive limit) is expressed as the percentage of gas or vapor dispersed in air that will burn when an ignition source is present. The temperature, the flammable range, and the potential for a vapor or gas to travel to an ignition source and flash back may affect rescue activities. The flammable range may indicate the need for special protective clothing. Most chemical-resistant protective clothing is neither heat- nor flame-resistant and may melt if a fire occurs.

Incompatibilities

HAZMAT incidents commonly involve more than one chemical. Incompatibility and reactivity information, primarily from the NIOSH Pocket Guide to Chemical Hazards, is included in this section.

Health Effects Section

- **Common symptoms**
- **Systemic effects and mechanism of action**

Health risk depends on the intrinsic toxic potential of the chemical, its concentration, and the duration of exposure. Highly toxic chemicals may pose a risk of illness even if the exposure duration is brief or the concentration of the substance is low. Even mildly toxic substances, however, can be hazardous if the exposure is prolonged or the concentration is high.

Acute Exposure

When suspected or known, the mechanism of action is discussed.

Acute exposure is defined as chemical exposure of less than 14 days duration. Most HAZMAT incidents involve acute exposures that last only minutes, but the chemical concentration may be extremely high. Although HAZMAT incident exposures are likely to be short, risks of adverse health effects still exist. The onset of health effects caused by acute exposure can be immediate or delayed.

Organ systems or metabolic processes that are adversely affected by the chemical are discussed in the following sections. The organ system or metabolic process mentioned first in each chemical protocol is the most severely affected, those not affected by the chemical are not addressed.

Cardiovascular

Many chemicals have direct depressant or stimulatory effects on cardiac function. Hypotension and dysrhythmias may be aggravated by hypoxia from respiratory depression or pulmonary aspiration of gastric contents. Hypotension may also occur because of volume depletion from excessive vomiting, diarrhea, or severe chemical burns.

Certain solvents (e.g., chlorinated hydrocarbons, freons, aromatic hydrocarbons) may lower the myocardial threshold to the dysrhythmogenic effects of catecholamines. For several hours after solvent exposure, a victim may be susceptible to ventricular dysrhythmias (e.g., premature ventricular contractions, ventricular tachycardia, or ventricular fibrillation) especially from administered sympathomimetic drugs such as bronchodilators or dopamine or the increased quantity of endogenous epinephrine produced during intense physical activity.

CNS Central nervous system (CNS) depressants (e.g., hydrocarbon solvents) cause a generalized decrease in brain activity. Headache, dizziness, confusion, lethargy, stupor, or coma may result. Severe depression of the brain stem can cause respiratory arrest and cardiovascular collapse. Some chemical depressants have early stimulatory effects, producing euphoria and giddiness similar to ethanol.

CNS stimulants (e.g., organophosphate insecticides) can cause agitation, anxiety, delirium, and seizures. Excessive muscular activity associated with seizures can cause hyperthermia.

Dermal Dermal contact with chemicals can produce local injury; if absorbed, chemicals can also produce systemic effects. Local injuries (e.g., burns from mineral acids) usually are immediately obvious. However, a few chemicals (e.g., alkaline corrosives, hydrofluoric acid) cause a progressive penetrating injury that may not be apparent for hours.

The skin generally provides a relatively impermeable protective barrier. Many chemicals disrupt the skin's integrity by removing fats, producing chemical burns, or destroying cells. Physical injury such as thermal burns or traumatic events may also result in loss of the skin's barrier effect. Disruption of the normal protective barrier allows easier entry of chemicals into systemic circulation. Systemic illness can also occur without skin damage because many fat-soluble chemicals (e.g., some organophosphate insecticides) rapidly penetrate intact skin.

Electrolyte Some chemicals can produce effects on serum electrolytes (e.g., potassium, calcium, sodium) and total anion gap. Electrolyte imbalance can cause muscle weakness and cardiac dysrhythmias.

Gastrointestinal Nausea, vomiting, abdominal pain, and diarrhea are common symptoms after chemical exposure and may be due to direct gastrointestinal irritation or to systemic effects. Ingestion of some chemicals can also cause severe corrosive injury to the mouth, throat, esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Hematologic Components of the blood and blood-forming organs can be damaged by many chemicals (e.g., arsine, benzene). Most hematologic changes (e.g., hemolysis, methemoglobinemia, bone marrow suppression, and anemia) can be detected by blood tests or simply by the color or appearance of the blood

<i>Hepatic</i>	Some chemical exposures result in acute injury to the liver, which typically does not manifest for 2 to 3 days after exposure. At that time, laboratory tests will show abnormal liver function (e.g., elevated bilirubin or aminotransferase levels or increased prothrombin time). Toxic hepatitis may progress to liver failure and death.
<i>Immunologic</i>	Immunologic effects may include induced sensitivity and allergy.
<i>Metabolic</i>	Metabolic acidosis is the most common adverse metabolic effect that occurs after chemical exposure. Acidosis results from an accumulation of acid anions such as formic, lactic, or oxalic acid.
<i>Musculoskeletal</i>	Musculoskeletal damage due to chemical exposure is unusual. Some effects are arthritis and hardening, destruction, or cancer of the bone.
<i>Ocular</i>	<p>Most serious ocular injuries result from direct eye contact with corrosive liquids or solids. High concentrations of or prolonged exposures to gases or vapors may also injure the eye. Severe eye exposure carries a risk of blindness or other visual impairment and demands immediate evaluation by an ophthalmologist.</p> <p>Most patients who have eye injuries involving the conjunctival or corneal surfaces experience pain and irritation, excessive lacrimation, and possibly crusting and swelling of the eyelids. Generally, corneal damage causes intense pain and the sensation of a foreign body in the eye.</p>
<i>Peripheral Neurologic</i>	Peripheral nervous system effects can include changes in sensation, reduced reflexes, and impaired motor function. Effects are pronounced in the largest muscle groups such as those in the lower limbs.
<i>Renal</i>	Some chemicals injure the kidneys directly. In addition, any poisoning causing massive muscle destruction can lead to kidney injury from excessive myoglobin in the kidney tubules.
<i>Respiratory</i>	Inhalation of a chemical irritant (e.g., ammonia, chlorine) usually causes rapid onset of burning and irritation of the nose, throat, and upper respiratory tract. Painful coughing, wheezing, and stridor may develop. If the exposure is massive, death may rapidly ensue from upper airway obstruction, massive alveolar destruction, or asphyxiation. Chest radiography may indicate pulmonary edema when damaged lung cells allow fluid to leak into the alveoli (referred to as noncardiogenic pulmonary edema because the fluid

accumulation is not caused by left ventricular failure, which occurs in cardiogenic pulmonary edema).

The onset and location of respiratory symptoms is partially related to the water solubility of the inhaled chemical. Highly water-soluble gases, such as ammonia, cause rapid onset of symptoms (burning nose and throat, painful cough, stridor, wheezing) as the gases dissolve in the mucous membranes of the upper respiratory tract. However, less soluble gases such as phosgene are breathed deeply into the lower airways and typically cause only mild or no early symptoms; noncardiogenic pulmonary edema may develop after 12 to 36 hours.

Injury to the respiratory tract also can occur after ingestion of a chemical substance. The unconscious or convulsing patient may vomit and then, because of depressed airway protective reflexes, may aspirate gastric contents into the lungs. Pulmonary aspiration of an ingested hydrocarbon can cause severe pneumonitis. Hydrocarbons irritate the lung tissue and interfere with surface tension in the alveoli, disrupting gas exchange. Pulmonary aspiration can sometimes be prevented by inserting a cuffed endotracheal tube into the patient's airway or by placing the patient in a head-down, left-side position and using suction immediately if vomiting occurs.

Potential Sequelae

Known or suspected sequelae and the prognosis for recovery after an acute exposure are described in this section. Signs and symptoms expected at various stages of recovery and the potential for permanent deficits are presented.

Chronic Exposure

Repeated, low-level exposures, typically over a long period of time, may produce health effects that differ in type or degree from effects of acute exposure. Most information about chronic toxicity is from epidemiologic studies and case reports of workplace exposures. Because HAZMAT incidents are unlikely to involve repeated or long-term exposures, chronic health effects are outlined only briefly.

Some major concerns of patients who have experienced an acute chemical exposure are the risks of cancer, reproductive effects, or impaired fetal development. No data exist on these outcomes from acute exposure to most chemicals. However, to guide the clinician who must address these patient concerns, we have included carcinogenic, reproductive, and developmental effects that have resulted from chronic exposure to the chemical. It is not known whether the data from chronic exposures are applicable to victims who are acutely exposed in a HAZMAT incident.

Carcinogenicity

The cancer information included in this section is derived from assessments made by the Department of Health and Human Services (DHHS), the International Association for Research on Cancer (IARC), or the Environmental Protection Agency (EPA). These organizations develop ratings of chemicals that indicate the cancer-producing ability of the chemicals. The information included was based on the following hierarchy: DHHS is offered if available, then IARC, then EPA. Failure of these organizations to evaluate a chemical does not necessarily mean that the chemical does not cause cancer.

*Reproductive and
Developmental Effects*

Information about reproductive and developmental effects was obtained primarily from three data files that are included in TOMES Plus, a proprietary database of Micromedex, Inc., Denver, CO. These data files are Reprotext, edited by Betty J. Dabney, PhD; the Teratogen Information System (TERIS), developed by the University of Washington; and Shepard's Catalog of Teratogenic Agents, written by Thomas H. Shepard, MD. An additional source of information was Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO Report no. GAOLPEMD-92-3) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. The 30 chemicals are alcohol, arsenic, cadmium, carbon disulfide, carbon monoxide, chlordecone, chloroprene, DDT, DBCP, DES, ethylene dibromide, EGEE, EGME, ethylene oxide, gossypol, hexachlorobenzene, lead, lithium, mercury, nicotine, PBBs, PCBs, 2,4,5-T, TCDD, tobacco smoke, toluene, vinyl chloride, vitamin A, and warfarin.

The topic of reproductive hazards is controversial and emotionally charged. Potentially high risk to the fetus may warrant considering termination of the pregnancy. Most clinicians are not adequately prepared to help the patient make this decision. Expert assistance may be available from regional poison control centers, regional reproductive risk/teratogen information centers, or the MotherRisk Program. For more information, see Appendices I and III.

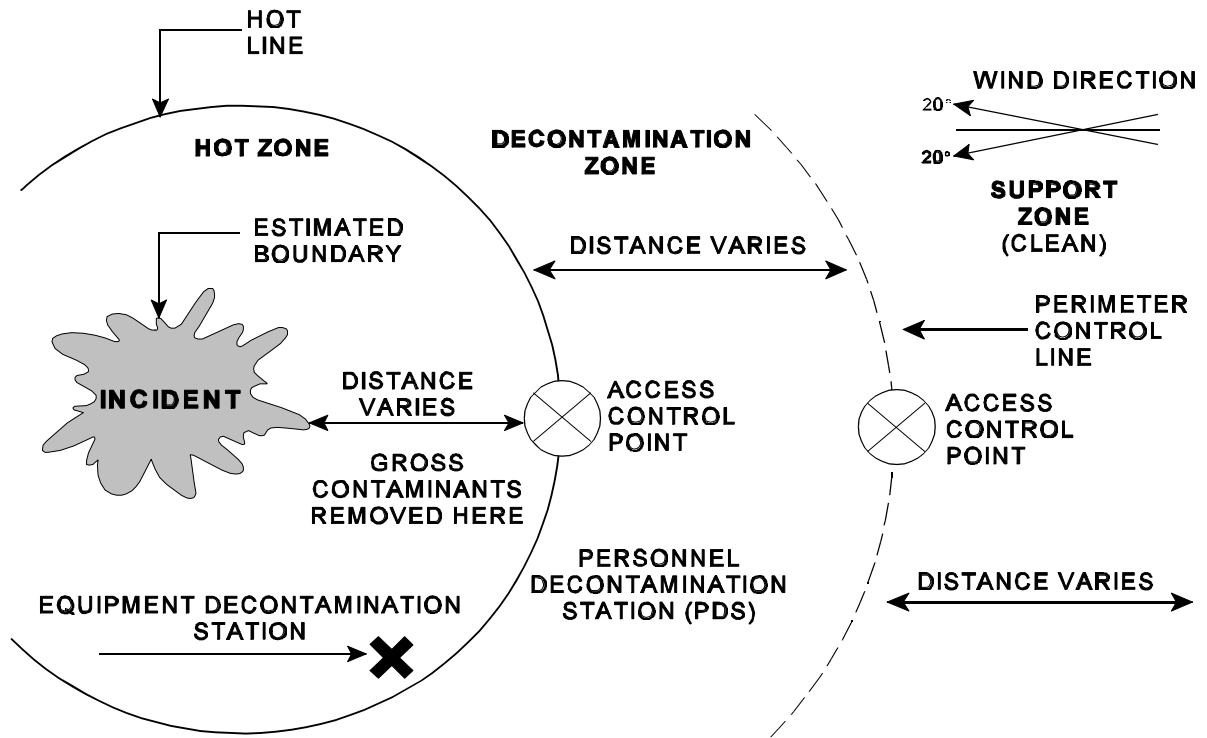
Prehospital Management Section

The Prehospital Management section describes the activities that typically occur in the three concentric areas surrounding a HAZMAT incident (Figures 1 and 2), particularly those activities that relate to Emergency Medical Services (EMS) personnel. The Hot Zone (or Exclusion Area) is the area surrounding the chemical release; it is assumed to pose an immediate health risk. The Decontamination Zone (or Warm Zone) is the area surrounding the Hot Zone where primary contamination is not expected but where personnel must use protective clothing and equipment to avoid chemical exposure from contaminated victims. The Support Zone (or Cold Zone) is the outermost ring where no exposure or risk is expected. The incident commander, medical personnel, and other support persons and equipment operate in the Support Zone. The information provided in the chemical protocols is an attempt to offer an accurate and practical approach to the management of hazardous materials emergencies. ‘The user of the protocols should be aware that large data gaps exist in the scientific literature.

Goals of the EMS HAZMAT Responder

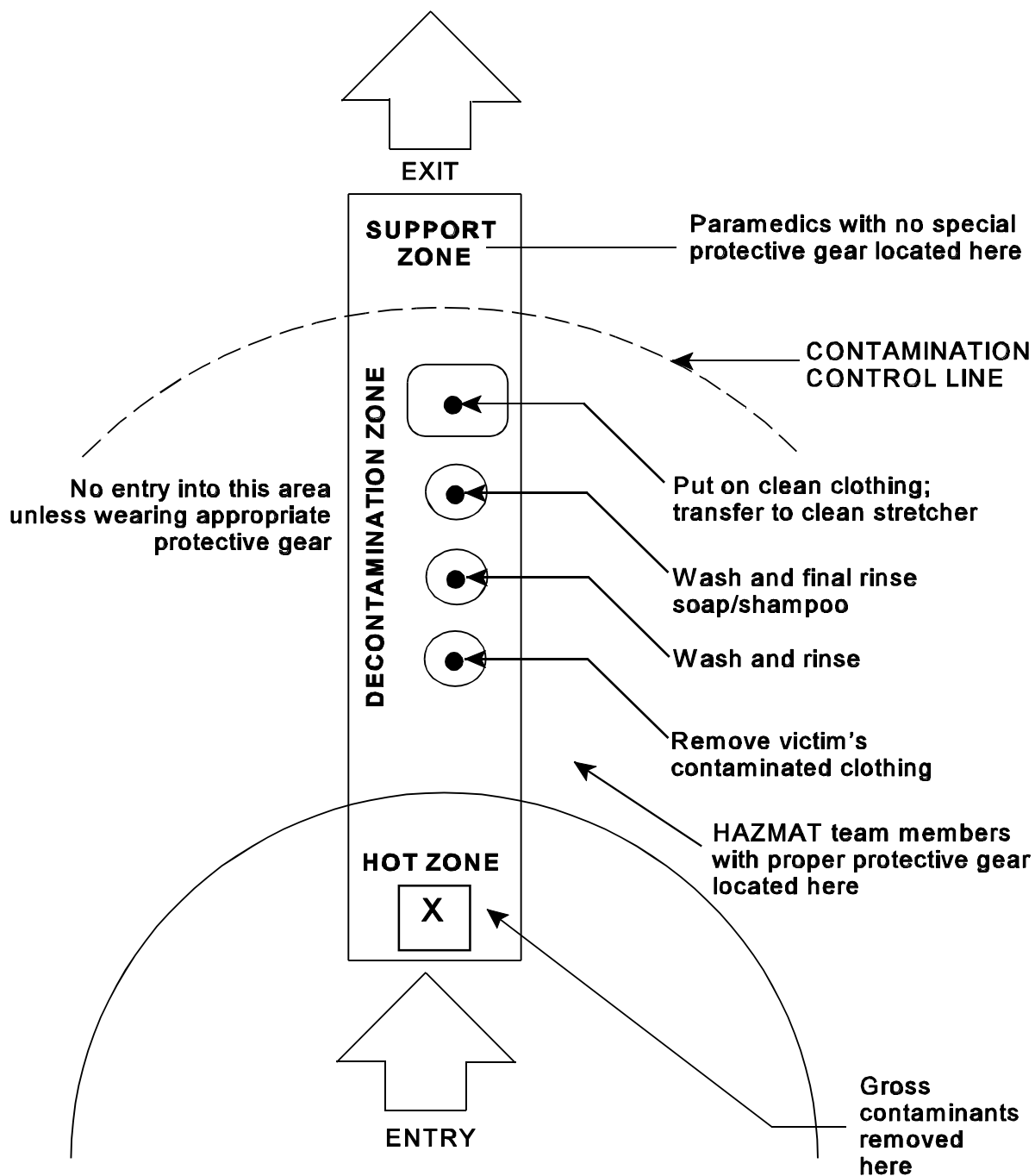
- Protect yourself. Approach the Scene cautiously, arriving upwind. Maintain a safe distance and inspect the scene from a nearby elevated area such as a hill. Respect the established exclusion zones and resist the temptation to rush in to attempt a rescue. If a command post has been established, report to the incident commander.
- Identify the chemical. Be familiar with the Department of Transportation (DOT) placard system, the National Fire Protection Association (NFPA) hazard labeling system, Material Safety Data Sheets (MSDS), and shipping papers.
- Consult the appropriate protocol and local sources to obtain information about the chemical, its health effects, and medical treatment.
- Determine the potential for secondary contamination. Understand the risk to yourself and to others in the Support Zone, ambulance, or hospital if decontamination is not completed at the scene.
- Perform appropriate and thorough decontamination.
- Provide basic and advanced life support (ALS).
- Transport victims to an appropriate medical facility as quickly as possible.

Figure 1. Organization of a HAZMAT incident area



Adapted from Olson, KR, ed. Poisoning and drug overdose. Norwalk, CT: Appleton and Lange, 1990.

Figure 2. Detail of decontamination zone



Adapted from Hazardous material medical management protocols, 2nd edition. Sacramento, CA: Emergency Medical Services Authority, 1991.

Prehospital Management Section

- **Potential for secondary contamination**
- **Health effects expected from an acute exposure**
- **Patient care (supportive care, antidotes)**

Secondary contamination is discussed on page 3 of the *Introduction*.

In the prehospital setting, the key factors in determining the potential for secondary contamination are the route and extent of exposure. Victims exposed only to gas or vapor are not likely to carry significant amounts of chemical beyond the Hot Zone and are not likely to endanger personnel outside the Hot Zone. However, victims whose skin, hair, or clothing is grossly contaminated with solid or liquid chemical (including condensed vapor) may contaminate personnel by direct contact or by off-gassing vapor. Victims who have ingested a toxic chemical may expose others through toxic vomitus or by vapor off-gassing from toxic vomitus.

The bold text below is from the Unidentified Chemical protocol. It is presented as an example of the information presented in each section. The plain text provides details or an explanation.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

The Hot Zone includes the area immediately around the chemical spill where persons may be in danger from chemical exposure or physical hazards (e.g., fire or explosion). Only persons who have specialized HAZMAT training should enter the Hot Zone. Although some of these persons may be trained as paramedics, only limited medical care can be provided in the Hot Zone. Advanced medical care is provided in the Decontamination Zone and Support Zone.

Rescuer Protection

When a chemical is unidentified, worst-case possibilities concerning toxicity must be assumed. The potential for severe local effects (e.g., irritation and burning) and severe systemic

effects (e.g., organ damage) should be assumed when specific rescuer-protection equipment is selected.

Respiratory Protection: Pressure-demand, self-contained breathing apparatus (SCBA) should be used in all response situations.

Skin Protection: Chemical-protective clothing should be worn when local and systemic effects are unknown.

Trained responders should select protective equipment and clothing based on the general regulations in 29 CFR 1910.120 (OSHA Hazardous waste operations and emergency response).

The protocols contain chemical-specific recommendations for rescuer protection. The Rescuer Protection section begins with a summary of the health hazards that are pertinent for one-time, short-term exposures such as those expected at a HAZMAT incident. The respiratory-tract and skin protection (e.g., respirators and chemical-protective clothing) recommendations are based on these health hazards.

Two basic types of respiratory protection are available: atmosphere-supplying and air-purifying respirators. Atmosphere-supplying respirators provide compressed air at greater than atmospheric pressure to a face mask that is worn by the rescuer and may be supplied-air or self-contained.

The self-contained breathing apparatus (SCBA) is often used in HAZMAT incident response to prevent inhalation of hazardous chemicals because it is self-contained, portable, and familiar. SCBA consists of a facepiece that seals, a tank of compressed air carried on the back, and a hose that runs from the air tank to the facepiece. The specific type of SCBA recommended in the Guidelines is “pressure demand”; that is, although air is always flowing into the facepiece (pressure), the flow increases in response to inhalation (demand).

Although commonly used at hazardous waste clean-up sites, the supplied-air respirator should not be used at a HAZMAT incident. The supplied-air respirator consists of a mask or facepiece connected to an air hose supplied by a compressor at a distant site. Because the air hose may be degraded by chemicals or heat and the hose may become tangled, the supplied-air respirator is not practical for operations during an emergency.

Air-purifying respirators do not supply air to the user; they simply filter the ambient air and are seldom used at HAZMAT incidents. Air-purifying respirators can use the same type of facepiece as an air-supplied respirator. Instead of an air-supply hose, they are connected to a charcoal or other filter-containing cartridge. The cartridge filters the air before it is inhaled. Conditions that preclude the use of an air-purifying respirator include

- oxygen-deficient atmosphere (19.5% O₂)
- unidentified contaminant
- unknown concentration of contaminant
- concentration of contaminant above NIOSH IDLH
- high relative humidity

Most HAZMAT incidents involve at least one of these conditions; therefore, air-purifying respirators are rarely appropriate for emergency response.

Dust or surgical masks are also air-purifying—they filter and prevent the inhalation of large particles. However, they offer no protection from the inhalation of chemical vapors or gases and are not recommended in the Guidelines.

Regardless of the type of respiratory protection used, all respirators should be approved by NIOSH and the Mine Safety and Health Administration (MSHA). NIOSH and MSHA designate performance characteristics of respirators.

Chemical-protective clothing (CPC) is not subject to performance standards set by a government agency. Chemical-specific resistance to degradation, penetration, and permeation are important factors to consider in selecting CPC. CPC that fails can subject the wearer to significant exposure and adverse health effects. Degradation involves the chemical breakdown of the suit material itself, causing exposure. Penetration is movement of a chemical through an opening in the material or article of clothing (e.g., through punctures or zippers). Permeation involves chemical movement through the suit material but not necessarily destruction of it.

The NFPA has established performance standards for two types of chemical-protective garments: a vapor-protective suit and a liquid-splash-protective suit. The standards provide methods for testing material and suits to assure chemical resistance, overall durability, and valve/closure construction suitability. The vapor protective suit is completely encapsulating; once the user is attired, even exhaled air is trapped inside until pressure activates

one-way release valves. Suits meeting the NFPA guidelines can be used to provide protection according to the EPA classifications described below. The certification accompanying protective clothing that meets NFPA guidelines specifies the chemicals and conditions under which the clothing was tested. The NFPA performance standards do not address respiratory protection; therefore, no assumptions can be made regarding respiratory protection based on the NFPA suit designation.

EPA has established a 4-stage classification system to address the levels of protection afforded by respiratory and chemical-protective clothing combinations commonly used by HAZMAT responders. The four classes, in descending order of protection, are called levels A through D. The EPA definitions do not address NFPA clothing; however, the equivalent NFPA suit is specified below.

Level A includes a fully encapsulating chemical-resistant suit (equivalent to an NFPA vapor-protective suit) and a pressure-demand SCBA.

Level B includes a nonencapsulating chemical-resistant suit (equivalent to an NFPA splash-protective suit) and an SCBA.

Level C includes a nonencapsulating chemical-resistant suit (equivalent to an NFPA splash-protective suit) and an air-purifying respirator.

Level D consists of work clothes that do not provide any specific respiratory or skin protection.

The EPA classification does not address use of the common fire-fighting ensemble - SCBA with “turnouts” or “bunker” gear. Turnouts are not designed to protect against chemical exposure and should not be worn when hazardous chemical exposure is possible.

Specialized personal protective gear should be used only by those with prior training and fitting. The choice of specific chemical-resistant materials (e.g., Tyvek, Saranex, or butyl rubber) is beyond the scope of this document and is generally the responsibility of an expert on the HAZMAT team. Additional protective equipment may be required when risks of fire or explosion exist.

Although CPC provides protection against adverse health effects due to chemical exposure, it contributes to heat stress. CPC prevents both the inward and outward movement of moisture, decreasing the availability of evaporative cooling. During an incident, body heat builds quickly because of the heavy workload and CPC prevents heat dissipation. Several cooling systems are available for use under CPC; however, they serve only to reduce peripheral body temperature and not core body temperature. Because core body temperature does not decrease, cooling systems may actually be harmful. By cooling the skin and making the user feel more comfortable, cooling systems may encourage rescuers to work longer and build up a dangerously high core body temperature.

ABC Reminders

Quickly ensure a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Only minimal patient care can be performed in the Hot Zone while wearing Level A or Level B protective gear. Rescuers can often perform only simple maneuvers such as ensuring a patent airway, applying a cervical collar, brushing off gross contaminants, and applying direct pressure to stop arterial bleeding. The goal in the Hot Zone is to quickly remove the victim from continued exposure and risk.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Victims should be removed from the Hot Zone to the Decontamination or Support Zone, as appropriate, in the safest and quickest way possible. Ambulatory victims may need to be guided to the Decontamination Zone. Nonambulatory victims can be removed on backboards, litters, or gurneys, or if necessary, carefully dragged or carried to safety.

Decontamination Zone

Victims exposed only to gas or vapor who have no skin or eye irritation may be transferred immediately to the Support Zone. All others require decontamination (see Basic Decontamination, page 25).

The Decontamination Zone is a corridor between the Hot Zone and the Support Zone. The Decontamination Zone may be set up in any convenient location that is safely beyond the Hot Zone, but

separate from the Support Zone. If possible, the Decontamination Zone should be established outdoors (preferably upwind and uphill from the Hot Zone) where natural ventilation will allow dispersion of vapor off-gassing from contaminated victims. Because personnel in the Decontamination Zone normally require protective gear, only trained HAZMAT-team members should be present.

Decontamination is not required for all victims. Victims exposed only to gases or vapor who do not have skin or eye irritation generally do not need decontamination. Victims who have been decontaminated or who do not require decontamination should be transferred immediately to the Support Zone.

Rescuer Protection

If the chemical or concentration is unidentified, personnel in the Decontamination Zone should wear the same protective equipment used in the Hot Zone (see Rescuer Protection, page 19).

Personnel in the Decontamination Zone normally require protective gear; only personnel with prior fitting and training should be permitted to don protective gear. Generally, the level of clothing is the same as that worn in the Hot Zone. A lower level of protective clothing can be used when the risk of secondary contamination is low. For example, a nonencapsulating suit (NFPA splash protective suit) can be used if an encapsulating suit (NFPA vapor-protective suit) is required in the Hot Zone. If the risk of inhaling off-gassing vapors is also low (i.e., the chemical is not highly volatile or the decontamination area is set up outside with good natural ventilation), it may be acceptable to use a lower level of respiratory protection. Air contaminants must be identified and measured to assure safety before a lesser level of respiratory protection is used.

ABC Reminders

Quickly ensure a patent airway. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag valve-mask device if necessary.

To provide airway, breathing, and circulatory support for patients in the Decontamination Zone, the rescuer may have to establish an artificial airway, administer supplemental oxygen or nebulized bronchodilators, and assist ventilation. Direct pressure should be applied to control heavy bleeding. Depending on the concentration of the chemical and its potential for secondary contamination, victims with serious trauma or medical complications (e.g.,

seizures) may have to wait for advanced medical care until gross contamination is removed.

Rescuers wearing respirators and heavy gloves will find it difficult to provide advanced medical care such as inserting an intravenous line or performing endotracheal intubation; therefore, this care is not administered until the victim is transferred to the Support Zone. Electronic equipment, such as cardiac monitors, generally are not taken into the Decontamination Zone because the equipment may not be safe to operate and may be difficult to decontaminate.

Basic Decontamination

Victims who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

Consider bagging the victim's jewelry and other valuables separately from clothing for easier retrieval later. Nonporous materials such as metal jewelry may be easy to decontaminate by washing, whereas clothing or shoes may require disposal. Leather items can be especially difficult to decontaminate and may need to be incinerated. Consult a HAZMAT specialist affiliated with the local fire department, the ATSDR/CDC Emergency Response 24-hour Hotline ([404] 639-0615) or the EPA Environmental Response Team, Edison, New Jersey ([732] 321-6740) for advice on the disposition of contaminated equipment and clothing.

Flush exposed or irritated skin and hair with water for 3 to 5 minutes. For oily or otherwise adherent chemicals, use mild soap on the skin and hair.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the Support Zone.

Many chemicals react violently with water, liberating toxic gases or creating explosions. Cautions about water reactivity (e.g., statement in the DOT Emergency Response Guidebook or in an MSDS) generally do not apply to flushing eyes, skin, and hair in the Decontamination Zone. There is little risk of creating a serious reaction hazard by adding large amounts of water to the small amount of residual chemical on the victim's body. In fact, the naturally occurring moisture on the skin is already reacting with

the chemical; hastening removal from the skin is preferable to leaving the chemical to further injure the victim.

Solids should be gently brushed from hair, skin, and clothing. During brushing, protect the victim's eyes, nose, and mouth. The length of time recommended for flushing exposed skin or eyes will vary with the chemical and the circumstances of exposure. Removal of oily or insoluble materials from the skin and hair requires washing with soap. Any liquid hand- or dish-washing soap will be satisfactory. Use only soft-bristled brushes; abrasive brushing may enhance skin injury and penetration. Most chemicals that cause only mild skin or eye irritation can be removed by flushing for 3 to 5 minutes. Ten to 15 minutes may be required for concentrated or strongly alkaline materials. Eye decontamination after exposure should be continued while the patient is transferred to the Support Zone and even during transport to a medical facility. An attempt should be made to remove contact lenses. Avoid forceful removal, which may inflict injury. Irrigation and transfer to the Support Zone should not be delayed because of difficulty in removing contact lenses.

Bleach, vinegar, or other solutions used for equipment decontamination should not be used for washing skin, hair, or eyes. Likewise, neutralizing agents should not be used for decontamination because the heat from neutralization may cause added injury. Dilution with large volumes of water is preferred for decontamination.

In cases of ingestion, do not induce emesis. Victims who are conscious and able to swallow should be given 4 to 8 ounces of water. Obtain medical care immediately.

Generally, vomiting should not be induced. Vomiting is relatively ineffective in emptying the stomach after a chemical ingestion and may be harmful to the victim. Vomiting may increase damage to the esophagus and stomach if irritating or corrosive chemicals have been ingested. The risk of pulmonary aspiration is also increased when vomiting occurs.

Activated charcoal adsorbs many chemicals and is relatively easy to administer. Unless a corrosive chemical has been ingested, a slurry of 50 to 60 grams of activated charcoal should be given to an adult patient who is awake and has a gag reflex. Charcoal may obscure the view when endoscopy is performed (at the hospital) to determine the extent of injury. See Ingestion Exposure, page

40, for further discussion of gastrointestinal-tract decontamination.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Victims should be moved from the Decontamination Zone to the Support Zone as soon as possible. Ambulatory patients can walk; others may require transport on a gurney.

Support Zone

Be certain that victims have been decontaminated properly. Victims who have undergone decontamination or have been exposed only to gas or vapor and who have no evidence of skin or eye irritation generally pose no serious risks of secondary contamination. In such cases, Support Zone personnel require no specialized protective gear.

Because the Support Zone is set up away from the dangers of physical hazards or chemical exposures, primary contamination is not a serious problem in this area. Personnel in the Support Zone do not require special protective clothing if victims have been decontaminated properly. An exception involves victims exposed to a potent and adherent chemical (e.g., an organophosphate pesticide), in which case the Support Zone team should wear disposable aprons or gowns and latex gloves.

ABC Reminders

Quickly ensure a patent airway. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Ensure adequate respiration; administer supplemental oxygen as required. Ensure a palpable pulse. Establish intravenous access if necessary. Attach a cardiac monitor. More sophisticated medical management can begin in the Support Zone where rescuer movement is less encumbered and more equipment and personnel are available. Initially, this care is centered on airway, breathing, and circulatory support for the patient. Intravenous lines should be inserted as soon as possible. A cardiac monitor should be attached because of the potential for some chemicals (e.g., halogenated or aromatic hydrocarbons) to produce dysrhythmogenic effects.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate.

In cases of ingestion, do not induce emesis. If the patient is conscious and able to swallow, administer 4

to 8 ounces of water if it has not been given previously. Obtain medical care immediately.

Some victims may require continued irrigation of irritated skin and eyes. If a cardiac monitor is required, irrigation should be completed before the monitor is attached. The additional decontamination recommendations do not imply that the victim poses a risk of secondary contamination. Exposure to a concentrated or strongly alkaline material may require continued irrigation of eyes and skin during transport and in the hospital. Eye irrigation is easily and conveniently accomplished using saline or water and intravenous tubing attached to a nasal canula placed over the bridge of the nose with the prongs pointed down toward the eyes.

Ingestion exposure is an uncommon occurrence in a HAZMAT incident. If ingestion has occurred and initial gastrointestinal decontamination has not been carried out in the Decontamination Zone, appropriate treatment must be instituted in the Support Zone. Gastrointestinal decontamination procedures should be carried out only if the patient is alert and has a gag reflex.

For most chemicals, the protocols do not recommend emesis and in some cases (e.g., exposure to corrosives or hydrocarbons), emesis is contraindicated. Many chemicals are effectively adsorbed on the surface of charcoal. When indicated in the protocol, a slurry of activated charcoal should be administered as soon as possible to prevent gastrointestinal absorption. If the chemical is corrosive or has not been identified, rinse the mouth and throat by administering 6 to 8 ounces of water. The water will also dilute the hazardous material in the stomach.

Advanced Treatment

Intubate the trachea in cases of respiratory compromise. When the patient's condition precludes endotracheal intubation, perform cricothyroidotomy if equipped and trained to do so.

Treat patients who have bronchospasm with aerosolized bronchodilators. Use these and all catecholamines with caution because of the enhanced risk of cardiac dysrhythmias after exposure to certain chemicals.

Patients who are comatose, hypotensive, or have seizures or cardiac dysrhythmias should be treated according to ALS protocols.

In the Support Zone, more advanced medical care can be readily administered. Contact the regional poison control center (see Appendix 1) or the hospital base station for advice specific to the incident.

Bronchodilators, such as metaproterenol (Alupent or Metaprel) or albuterol (Proventil or Ventolin), can be administered by metered-dose inhaler, or preferably, by hand-held nebulizer. However, these medications increase heart rate and may provoke cardiac dysrhythmias in victims who have been exposed to certain chlorinated or aromatic hydrocarbons. When bronchodilators are needed, the lowest effective dose should be given and cardiac rhythm should be monitored.

Evaluate the patient for possible opioid overdose or hypoglycemia and administer naloxone (Narcan) and dextrose according to standard ALS protocols. Consider the possibility that coma or seizures may be the result of trauma (e.g., head injury) rather than of chemical poisoning.

Administer specific antidotes as described in the chemical-specific protocols if within the prehospital scope of practice.

Transport to Medical Facility

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

The base station and receiving medical facility should be apprised of the patients' status. Special procedures for patient care en route can be discussed, especially if transport time will be lengthy. Notifying the medical facility of your arrival time ensures appropriate emergency department preparation.

Before transporting patients who have ingested hazardous materials, prepare the ambulance by lining a basin or bucket with open plastic bags to catch and isolate toxic vomitus. Some chemicals are converted to poisonous gases by the action of stomach acids (e.g., cyanide salts create hydrogen cyanide gas; sodium azide can produce hydrazoic acid gas). Toxic vomitus can contaminate personnel and equipment by direct contact or by off-gassing volatile chemicals.

Ambulances that transport HAZMAT victims require only standard equipment. Most supplies recommended in the *Guidelines* are standard equipment or are easily obtained from grocery or drug stores. The specific equipment most likely to be used in HAZMAT response will vary with the training and policies of individual emergency medical services agencies, but at a minimum include the following:

- disposable gloves
- splash goggles
- waterproof disposable shoe covers
- disposable gowns to cover EMS personnel clothing and to be used by stripped and decontaminated patients
- large supply of oxygen
- plastic garbage bags
- large wash basin or bucket (lined with plastic to isolate toxic vomitus)
- liquid soap
- saline and intravenous tubing for eye irrigation
- disposable towels to soak up toxic vomitus

Only decontaminated patients or patients not requiring decontamination should be transported. Some earlier HAZMAT protocols called for zipping patients into “body bags” without proper decontamination. If patients have been decontaminated effectively, no danger of secondary contamination exists. Use of the body bag technique is not effective and puts the victim at risk of substantial skin injury and absorption.

Multi-Casualty Triage

All exposed patients should be transported to a medical facility for evaluation.

Asymptomatic patients who have not had direct chemical exposure can be discharged from the scene after their names, addresses, and telephone numbers are recorded. Those discharged should be advised to seek medical care promptly if symptoms develop.

Consult with the base station physician or regional poison control center for further advice regarding triage of multiple victims.

Triage is a complex process that identifies victims who have the most serious injuries and who can benefit most from rapid treatment and transport. The Multi-Casualty Triage section in each protocol makes general recommendations for transport

priorities based only on the chemical; however, the base station physician or regional poison control center (see Appendix I) should give advice for specific situations.

Emergency Department Management Section

The *Guidelines*, which represent a state-of-the-art, practical approach to the management and treatment of HAZMAT victims, are based on the consensus of a panel of experts. However, the user of the protocols should be aware that large data gaps exist in the scientific literature and knowledge regarding the treatment of patients exposed to hazardous substances is constantly evolving. The protocols are not a substitute for the professional judgment of a health care provider and must be interpreted in light of specific information regarding the patient and in conjunction with other sources of authority.

Goals of the Hospital Provider in HAZMAT Incidents:

- Determine the potential for secondary contamination.
- If necessary, decontaminate patients.
- Provide supportive and antidotal emergency care (resources for toxicity information include the *Guidelines* and a regional poison control center [*Appendix I*]).
- Obtain appropriate laboratory tests.
- Arrange for observation, hospital admission, and follow-up care as needed.

Emergency Department Management Section

- **Potential for secondary contamination**
- **Health effects expected from an acute exposure**
- **Patient care (supportive care, antidotes)**

Secondary contamination is discussed on page 3 of the introduction. Victims who were exposed only to gas or vapor or who were decontaminated at the scene are not likely to pose a risk of secondary contamination to hospital personnel. However, victims whose skin, hair, or clothing is grossly contaminated with solid or liquid chemical (including condensed vapor) may endanger health care personnel by direct contact or by off-gassing vapor. Toxic vomitus can also expose hospital personnel directly or through off-gassing vapor.

Decontamination Area

Previously decontaminated patients and patients exposed only to gas or vapor who have no evidence of skin or eye irritation may be transferred immediately to the Critical Care Area. Other patients will require decontamination as described below.

Basic decontamination should be carried out at the scene of the incident before the victim is transported, however, this does not always occur. For example, a contaminated victim might be brought directly to the emergency department by a coworker. Hospitals should plan for the arrival of contaminated victims.

Contaminated victims received in indoor facilities create potentially serious risks of secondary contamination to hospital personnel, especially if materials are volatile. Many hospital protocols suggest shutting off the ventilation system to protect the hospital from cross-contamination. However, lack of ventilation may compound the risk to emergency department personnel attending the victim. Very few hospitals have the financial resources to properly construct a separate decontamination room with appropriate ventilation.

Basic decontamination is safely and practically performed outside in a naturally ventilated area adjacent to the ambulance entrance. Suggested equipment and supplies for an outdoor hospital Decontamination Area include the following:

- Gurney with plastic tub or run-off collector. (Several companies make disposable or reusable decontamination

tables or foldable rubber tubs that can be placed on top of a gurney.)

- A warm-water source with a hose and soft-stream shower head
- Disposable chemical-resistant jumpsuits (e.g., of Tyvek or Saranex)
- Chemical-resistant gloves (e.g., of butyl rubber) in different sizes
- Rubber aprons
- Mild soap and shampoo
- Soft-bristled brushes
- Splash-protective goggles or other protective eye wear
- Wading pool for decontamination of ambulatory patients
- Plastic garbage bags
- Oxygen tanks with delivery supplies
- Disposable towels and gauze
- Surgical scrubs for decontaminated patients
- Extra blankets and sheets for patient privacy and warmth
- Portable privacy barriers (do not totally enclose decontamination area or natural ventilation will be lost)

ABC Reminders

Evaluate and support airway, breathing, and circulation. Intubate the trachea in cases of respiratory compromise. If the patient's condition precludes Intubation, surgically create an airway.

Treat patients who have bronchospasm with aerosolized bronchodilators; use these and all catecholamines with caution because of the potential enhanced risk of cardiac dysrhythmias.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Generally, decontamination is performed before treatment is started. However, basic airway, breathing, and circulation must be addressed in victims who have life-threatening symptoms. Patients heavily contaminated with highly toxic organophosphate insecticides pose great risks of secondary contamination to health care personnel; patients should not be touched until staff is appropriately gloved and gowned. Persons soaked with flammable materials cannot be treated with DC countershock until decontamination has been carried out because of risk of fire and explosion. Simultaneous treatment and decontamination of patients should be carried out whenever possible.

Basic Decontamination

Patients who are able and cooperative may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings.

For easier retrieval, consider bagging the victim's jewelry and other valuables separately from clothing. Nonporous materials such as metal jewelry may be easy to decontaminate by washing, whereas clothing or shoes may require disposal. Leather items can be especially difficult to decontaminate and may need to be incinerated.

Flush exposed or irritated skin and hair with plain water for 3 to 5 minutes. For oily or otherwise adherent chemicals, use mild soap on the skin and hair. Rinse thoroughly with water.

Flush exposed or irritated eyes with plain water or saline for at least 5 minutes. Remove contact lenses if present and easily removable without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the patient to the Critical Care Area.

Some chemicals react violently with water, liberating toxic gases or creating explosions. Cautions about water reactivity (e.g., the statements in the DOT Emergency Response Guidebook or in an MSDS) generally do not apply when decontaminating victims with water. Adding large amounts of water to the small amount of residual chemical on the victim's body poses little risk of creating a serious reaction hazard. In fact, the naturally occurring moisture on the skin will react with the chemical; hastening removal of the chemical from the skin is preferable to leaving it to potentially cause further injury.

Solid contaminants should be gently brushed from hair, skin, and clothing. During brushing, protect the victim's eyes. The length of time for flushing exposed skin or eyes with water will vary with the chemical and the circumstances of exposure. Chemicals that cause only mild skin or eye irritation can be flushed for 3 to 5 minutes. Concentrated or strongly alkaline materials may require 10 to 15 minutes. Eye decontamination may be continued while the patient is transferred to the Critical Care Area. An attempt should be made to remove contact lenses. Avoid forceful removal that may inflict injury. Difficulty in removing contact lenses should not delay irrigation or transfer to the Critical Care Area.

Removal of oily or insoluble materials from the skin and hair requires washing with soap or shampoo. Any liquid hand- or dish-washing soap is satisfactory. Use only soft-bristled brushes; abrasive brushing may enhance skin injury and penetration.

Bleach, vinegar, or solutions used for decontaminating equipment should not be used for washing skin, hair, or eyes. Neutralizing agents should not be used because the heat of the neutralization may cause added injury. Flooding volumes of water are preferable.

In cases of ingestion, do not induce emesis. Administer 4 to 8 ounces of water to dilute stomach contents if the patient is conscious and able to swallow. Immediately transfer the patient to the Critical Care Area.

Emesis is not generally recommended in the protocols. Vomiting is relatively ineffective in emptying the stomach after a chemical ingestion and may be harmful to the victim. Vomiting may increase the risk of pulmonary aspiration or damage to the esophagus and stomach if irritating or corrosive chemicals have been ingested.

Activated charcoal adsorbs many chemicals and is relatively easy to administer. For most chemical ingestions, a slurry of 50 to 60 grams of activated charcoal should be administered to an adult patient who is awake and has a gag reflex. If a corrosive chemical has been ingested, do not administer activated charcoal because it may obscure the view when endoscopy is performed. See Critical Care Area below for further discussion of gastrointestinal decontamination.

Critical Care Area

If appropriate decontamination efforts have been completed before entry to the Critical Care Area, special precautions, such as covering floors and walls with plastic or shutting off the ventilation system, are not needed. However, if the patient has ingested a chemical, prepare to isolate toxic vomitus quickly (see Ingestion Exposure, page 40).

Be certain that appropriate decontamination has been carried out. (See Decontamination Area, page 33.)

ED personnel in the Critical Care Area generally do not need specialized protective gear. However, if risk of residual skin contamination exists (e.g., potent chemicals, such as some organophosphate pesticides, or radioactive dust), water-resistant gowns or aprons, latex gloves, and eye-splash protection are

necessary. Emergency medical care providers usually carry these protective items for universal infection control or communicable disease control.

ABC Reminders

Evaluate and support airway, breathing, and circulation as in ABC Reminders, page 34. Establish intravenous access in seriously ill patients. Continuously monitor cardiac rhythm.

Patients who are comatose, hypotensive, or have seizures or ventricular dysrhythmias should be treated in the conventional manner.

Many chemicals can cause progressive airway injury or systemic illness with delayed onset. Watch for signs of laryngeal edema and respiratory system compromise, such as progressive hoarseness, stridor, hypoventilation, or cyanosis.

Consider the possibility of exposure to multiple chemicals as well as multiple-system injuries. For example, smoke inhalation can cause airway injury because of heat and irritant chemicals and coma from asphyxiants such as carbon monoxide and cyanide.

Consider possible opioid overdose and evaluate for hypoglycemia; administer naloxone (Narcan) and dextrose according to usual protocols. Treat patients who have seizures with conventional anticonvulsants (e.g., diazepam, phenytoin, or phenobarbital). Consider the possibility that coma or seizures may be from a head injury or from alcohol or other drug intoxication, rather than from hazardous material exposure.

Place an intravenous line in all patients who are unconscious, obtunded, hypotensive, or may become so. Patients exposed to substances that may cause cardiac sensitization or intravascular hemolysis may also require intravenous access. An initial bolus of an appropriate intravenous solution should be given. The fluid should be titrated to maintain acceptable urine output and blood pressure. Care must be taken not to overhydrate the patient.

Treat patients who have hypotension using rapid infusions of normal saline (250 mL to 1 L in adults). Use dopamine or other inotropic drugs for persistent hypotension. Hypotension may be complicated by hypothermia or hyperthermia. Hypothermia should be considered if the victim was stripped and decontaminated with cold water or in a cold ambient setting. Hyperthermia may result from certain systemic poisons (e.g., dinitrophenol).

Inhalation Exposure

Administer supplemental oxygen by mask to patients who have respiratory complaints. Treat patients who have bronchospasm with aerosolized bronchodilators; use these and all catechola mines with caution because of the potential or possible enhanced risk of cardiac dysrhythmias.

Bronchodilators may provoke ventricular dysrhythmias in some patients who have been exposed to aromatic or halogenated hydrocarbons.

Although pulse oximetry is a convenient way to continuously monitor oxygenation in patients, it is unreliable or falsely normal in patients who have dyshemoglobinemias (e.g., methemoglobinemia or carboxyhemoglobinemia) because it measures only oxygen dissolved in the blood and not the status of tissue oxygenation. In patients who have altered hemoglobins, the pulse oximeter does not reflect the impaired oxygen carrying or delivery capacity of the red cells. In these situations, a Co-Oximeter should be used to measure specific levels of hemoglobins unable to transport oxygen.

Chemically induced pulmonary edema is due to leaky pulmonary alveoli, not left ventricular failure as is cardiogenic pulmonary edema. Patients who have chemically induced pulmonary edema do not benefit from digoxin, morphine, afterload reduction, or diuretics. Supplementary oxygen, delivered by mechanical ventilation and positive end-expiratory pressure, if needed, are standard treatments for chemically induced (noncardiogenic) pulmonary edema.

Corticosteroids and antibiotics have been commonly recommended for treatment of chemical pneumonitis, but their effectiveness has not been substantiated.

Soluble irritants (e.g., ammonia or hydrogen chloride) rapidly produce respiratory effects; poorly soluble irritants (e.g., phosgene and some nitrogen oxides) produce slow onset of airway irritation and respiratory distress. Poorly soluble agents are commonly associated with delayed (12 to 72 hours) onset pulmonary edema. The time period for developing pulmonary edema varies with the chemical and is noted in each individual protocol. Watch for signs of respiratory distress and intubate if necessary.

Skin Exposure

If chemical burns are present, treat as thermal burns.

The extent and depth of injury in a chemical burn is often not immediately apparent; hence the severity of the burn is frequently underestimated. Loss of circulating fluid may occur. In addition, dermal absorption of a corrosive chemical may contribute to systemic toxicity.

Patients who have been exposed to highly corrosive, penetrating, oily, or persistent chemicals may require additional or continuous decontamination. Residues may remain in the armpits, groin, buttocks, hair, ears, nostrils, and under the fingernails and toenails. If the material is highly contaminating (e.g., organophosphate pesticides or radioactive dust), care givers should wear gowns and gloves to protect themselves.

Use liquid soap for cleansing the skin and hair. Special decontaminating agents are recommended for only a few chemicals (see specific protocols).

Eye Exposure

Ensure that adequate eye irrigation has been completed. Test visual acuity. Examine the eyes for corneal damage using a magnifying device or a slit lamp and fluorescein stain. For small corneal defects, use ophthalmic antibiotic ointment or drops, analgesic medication, and an eye patch. Immediately consult an ophthalmologist for patients who have corneal injuries.

Ensure that contact lenses have been removed, that no visible residual material is in the conjunctival sac, and that the pH of the conjunctival fluid is normal.

Irrigation is easily continued in a hospital setting using intravenous tubing to provide a steady, low-pressure stream of water or saline. A Morgan Lenscan also be placed to provide continuous, thorough eye decontamination. Do not use neutralizing or other decontaminating solutions.

A corneal burn or abrasion can easily be seen with the aid of fluorescein stain, a UV light source, and a magnifier or slit lamp. The disrupted corneal surface allows accumulation of the fluorescein, which fluoresces under UV light. If serious injury is evident (e.g., extensive corneal fluorescein accumulation, cloudy or bloody material in the anterior chamber, or obvious perforation of the globe), an ophthalmologist should be consulted immediately.

Ingestion Exposure

Do not induce emesis. If the patient is alert and charcoal has not been given previously, administer a slurry of activated charcoal. If a corrosive material is suspected, administer 4 to 8 ounces of water; do not give a slurry of activated charcoal. Consider endoscopy to evaluate the extent of gastrointestinal-tract injury. If a large dose has been ingested and the patient's condition is evaluated within 30 minutes after ingestion, consider gastric lavage.

Ingested chemicals and products formed by their reaction with stomach acid may be hazardous to ED personnel through direct contact with vomitus or by inhalation of the gases liberated from the vomitus. For example, ingested cyanide salts are converted to highly toxic hydrogen cyanide gas in the stomach. Staff must take measures, therefore, to isolate toxic vomitus or gastric washings. This can be done by attaching the lavage tube to isolated wall suction or other closed container.

Activated charcoal is capable of adsorbing most chemicals and should be given as early as possible. Even chemicals that have relatively poor adsorption to charcoal (e.g., cyanide and alcohols) are still bound to some extent. Charcoal may need to be removed by gastric washing before endoscopy can be performed. Corrosive liquids should be removed from the stomach as early as possible. However, care must be taken when placing the gastric tube because blind gastric-tube placement may further injure the chemically damaged esophagus or stomach.

Antidotes and Other Treatments

Treatment consists of supportive measures.

The individual guidelines provide information on the use of specific antidotes.

Laboratory Tests

Routine laboratory studies for all exposed patients include CBC, glucose, and electrolyte determinations. Additional studies for patients exposed to an unidentified chemical include ECG monitoring, renal-function tests, and liver-function tests. Chest radiography and pulse oximetry (or ABG measurements) are recommended for severe inhalation exposure.

All patients should have CBC, glucose, and electrolyte determinations. Additional, specific recommendations are listed in the laboratory tests section to aid both diagnosis and treatment.

Laboratory test results are often within normal range immediately after an exposure but may become abnormal after a delay of several hours or even days, depending on the specific chemical exposure. For example, chest radiography may not show signs of pulmonary edema for 12 to 24 hours and signs of liver injury may not appear for 2 to 3 days following exposure. Pulse oximetry and routine arterial blood gas determination of P_{O_2} tests may provide falsely normal, unreliable, or misleading results in patients with abnormal hemoglobin states (e.g., methemoglobinemia or carboxyhemoglobinemia).

Tests to measure a specific chemical contaminant in biologic samples are rarely available on an emergency basis. The turn-around time may be several hours to days; hence, these tests rarely are clinically useful. However, the results of these tests may aid in confirming or documenting exposure. A regional poison control center (*Appendix I*) can assist with the selection and interpretation of specialized laboratory tests.

Disposition and Followup

Consider hospitalizing patients who have a suspected serious exposure and persistent or progressive symptoms.

Patient disposition should be determined based on the symptoms, the intrinsic toxicity of the chemical, and course of illness. Some patients may be safely discharged from the emergency department while others will require prolonged observation or intensive care.

Delayed Effects

When the chemical has not been identified, the patient should be observed for an extended period or admitted to the hospital.

The usual duration of observation in an emergency department is 6 to 8 hours. If the chemical agent is known to produce delayed-onset illness or is unidentified, the asymptomatic patient should be admitted for observation.

Patient Release

Asymptomatic patients who have minimal exposure, normal initial examinations, and no signs of toxicity after 6 to 8 hours of observation may be discharged with instructions to seek medical care promptly if symptoms develop.

Each protocol includes a detailed Patient Information Sheet with a list of possible delayed symptoms. This sheet should be reviewed with the patient before discharge. A signed copy should be

included in the medical chart, and a copy sent home with the patient.

Do not release clothing or personal items to the patient before a determination of residual contamination is made. Most items can be reused after washing. However, some contaminated articles cannot be rendered safe for reuse (e.g., leather goods, such as shoes, that are contaminated with methyl bromide or organophosphate pesticides). Some articles will require disposal at a hazardous waste site or by incineration. Consult a HAZMAT specialist affiliated with the local fire department or the ATSDR/CDC Emergency Response 24-hour Hotline ([404] 639-0615) for advice on the disposition of contaminated personal effects.

Followup

Provide the patient with follow-up instructions to return to the emergency department or a private physician to reevaluate initial findings. Patients who have corneal injuries should be reexamined within 24 hours.

Appendix II contains the telephone numbers and addresses of members of the Association of Occupational and Environmental Clinics (AOEC). These clinics employ specialists in the diagnosis and treatment of chemically exposed patients. They may provide consultation and follow-up advice.

Reporting

If a work-related incident has occurred, you may be legally required to file a report; contact your state or local health department.

Other persons may still be at risk in the setting where this incident occurred. If the incident occurred in the workplace, discussing it with company personnel may prevent future incidents. If a public health risk exists, notify your state or local health department or other responsible public agency. When appropriate, inform patients that they may request an evaluation of their workplace from OSHA or NIOSH. See *Appendices III and IV* for a list of agencies that may be of assistance.

Appendix III contains the telephone numbers of state health departments. In addition to filing a report, state health departments or the EPA's Environmental Response Team, Edison, New Jersey ([732] 321-6740) may be able to assist in determining procedures for the cleaning of hospital facilities and equipment.

You may also advise your patients to call the regional OSHA office to report a suspected violation of safe work practices. Appendix IV contains the numbers of the NIOSH office that may be of assistance.

Patient Information Sheet

The Patient Information Sheet provides information and follow-up instructions for persons who have been exposed to the chemical. It is written in an easy to understand question and answer format and addresses the questions most often asked. It is intended to be given to the patient.

The follow-up instructions on the back of the Patient Information Sheet are statements that the clinician can check off if they apply to the patient. The instructions include a list of signs and symptoms specific to each chemical (and directions to the patient to seek medical care if they occur); directions for obtaining follow-up appointments; and restrictions on activities, medications, alcohol and cigarette smoke. Space is provided for the clinician to write other instructions.

