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Law Enforcement and Corrections Standards and Testing Program

Guide for the Selection of Chemical and Biological Decontamination Equipment for Emergency First Responders

NIJ Guide 103–00

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ABOUT THE LAW ENFORCEMENT AND CORRECTIONS STANDARDS AND TESTING PROGRAM

The Law Enforcement and Corrections Standards and Testing Program is sponsored by the Office of Science and Technology of the National Institute of Justice (NIJ), U.S. Department of Justice. The program responds to the mandate of the Justice System Improvement Act of 1979, which directed NIJ to encourage research and development to improve the criminal justice system and to disseminate the results to Federal, State, and local agencies.

The Law Enforcement and Corrections Standards and Testing Program is an applied research effort that determines the technological needs of justice system agencies, sets minimum performance standards for specific devices, tests commercially available equipment against those standards, and disseminates the standards and the test results to criminal justice agencies nationally and internationally.

The program operates through:

The *Law Enforcement and Corrections Technology Advisory Council* (LECTAC), consisting of nationally recognized criminal justice practitioners from Federal, State, and local agencies, which assesses technological needs and sets priorities for research programs and items to be evaluated and tested.

The *Office of Law Enforcement Standards* (OLES) at the National Institute of Standards and Technology, which develops voluntary national performance standards for compliance testing to ensure that individual items of equipment are suitable for use by criminal justice agencies. The standards are based upon laboratory testing and evaluation of representative samples of each item of equipment to determine the key attributes, develop test methods, and establish minimum performance requirements for each essential attribute. In addition to the highly technical standards, OLES also produces technical reports and user guidelines that explain in nontechnical terms the capabilities of available equipment.

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Guide for the Selection of Chemical and Biological Decontamination Equipment for Emergency First Responders

NIJ Guide 103–00 Volume I

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We wish to acknowledge the Interagency Board (IAB) for Equipment Standardization and Interoperability. The IAB (made up of government and first responder representatives) was commissioned by the Attorney General of the United States in conjunction with the Department of Defense's Director of Military Support. The IAB was established to ensure equipment standardization and interoperability and to oversee the research and development of advanced technologies to assist first responders at the State and local levels in establishing and maintaining a robust crisis and consequence management capability.[3]

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[3]The Marshall Convention, Standardized Weapons of Mass Destruction (WMD) Response Force Equipment and InterOperability, 2 to 4 November 1999.

FOREWORD

The Office of Law Enforcement Standards (OLES) of the National Institute of Standards and Technology (NIST) furnishes technical support to the National Institute of Justice (NIJ) program to support law enforcement and criminal justice in the United States. OLES's function is to develop standards and conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

OLES is: (1) subjecting existing equipment to laboratory testing and evaluation, and (2) conducting research leading to the development of several series of documents, including national standards, user guides, and technical reports.

This document covers research conducted by OLES under the sponsorship of the NIJ. Additional reports as well as other documents are being issued under the OLES program in the areas of protective clothing and equipment, communications systems, emergency equipment, investigative aids, security systems, vehicles, weapons, and analytical techniques and standard reference materials used by the forensic community.

Technical comments and suggestions concerning this guide are invited from all interested parties. They may be addressed to the Office of Law Enforcement Standards, National Institute of Standards and Technology, 100 Bureau Drive, Stop 8102, Gaithersburg, MD 20899–8102.

Sarah V. Hart, Director
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COMMONLY USED SYMBOLS AND ABBREVIATIONS

A	ampere	h	hour	o.d.	outside diameter
ac	alternating current	hf	high frequency	Ω	ohm
AM	amplitude modulation	Hz	hertz	p.	page
cd	candela	i.d.	inside diameter	Pa	pascal
cm	centimeter	in	inch	pe	probable error
CP	chemically pure	IR	infrared	pp.	pages
c/s	cycle per second	J	joule	ppm	parts per million
d	day	L	lambert	qt	quart
dB	decibel	L	liter	rad	radian
dc	direct current	lb	pound	rf	radio frequency
°C	degree Celsius	lbf	pound-force	rh	relative humidity
°F	degree Fahrenheit	lbf·in	pound-force inch	s	second
dia	diameter	lm	lumen	SD	standard deviation
emf	electromotive force	ln	logarithm (base e)	sec.	section
eq	equation	log	logarithm (base 10)	SWR	standing wave ratio
F	farad	M	molar	uhf	ultrahigh frequency
fc	footcandle	m	meter	UV	ultraviolet
fig.	figure	min	minute	V	volt
FM	frequency modulation	mm	millimeter	vhf	very high frequency
ft	foot	mph	miles per hour	W	watt
ft/s	foot per second	m/s	meter per second	N	newton
g	acceleration	mo	month	λ	wavelength
g	gram	N·m	newton meter	wk	week
gr	grain	nm	nanometer	wt	weight
H	henry	No.	number	yr	year

area=unit^2 (e.g., ft^2, in^2, etc.); volume=unit^3 (e.g., ft^3, m^3, etc.)

ACRONYMS SPECIFIC TO THIS DOCUMENT

CB	Chemical and Biological	LCt_{50}	(Lethal Concentration Time) $_{50}$
DETA	Diethylenetriamine	NFPA	National Fire Protection Association
DS2	Decontaminating Solution 2	PPE	Personal Protection Equipment
SF	Selection Factor	SDK	Skin Decontamination Kit
EGME	Ethylene Glycol Monomethylether	TBD	To Be Determined
IDLH	Immediately Dangerous to Life and Health	TICs	Toxic Industrial Chemicals
IAB	Interagency Board	TIMs	Toxic Industrial Materials

PREFIXES (See ASTM E380)

d	deci (10^{-1})	da	deka (10)
c	centi (10^{-2})	h	hecto (10^{2})
m	milli (10^{-3})	k	kilo (10^{3})
µ	micro (10^{-6})	M	mega (10^{6})
n	nano (10^{-9})	G	giga (10^{9})
p	pico (10^{-12})	T	tera (10^{12})

COMMON CONVERSIONS

0.30480 m = 1 ft	4.448222 N = 1 lbf
2.54 cm = 1 in	1.355818 J = 1 ft·lbf
0.4535924 kg = 1 lb	0.1129848 N m = 1 lbf·in
0.06479891g = 1gr	14.59390 N/m = 1 lbf/ft
0.9463529 L = 1 qt	6894.757 Pa = 1 lbf/in^2
3600000 J = 1 kW·hr	1.609344 km/h = 1 mph

psi = mm of Hg x (1.9339×10^{-2})
mm of Hg = psi x 51.71

Temperature: $T_{°C} = (T_{°F} - 32) \times 5/9$ Temperature: $T_{°F} = (T_{°C} \times 9/5) + 32$

ABOUT THIS REPORT

The National Institute of Justice is the focal point for providing support to State and local law enforcement agencies in the development of counterterrorism technology and standards, including technological needs for chemical and biological defense. In recognizing the needs of State and local emergency first responders, the Office of Law Enforcement Standards (OLES) at the National Institute of Standards and Technology (NIST), working with the National Institute of Justice, the Technical Support Working Group, the U.S. Army Soldier and Biological Chemical Command, and the Interagency Board, is developing chemical and biological defense equipment guides. The guides will focus on chemical and biological equipment in areas of detection, personal protection, decontamination, and communication. This document focuses specifically on chemical and biological decontamination equipment and was developed to assist the emergency first responder community in the evaluation and purchase of decontamination equipment.

The long range plans are to: (1) subject existing decontamination equipment to laboratory testing and evaluation against a specified protocol, and (2) conduct research leading to the development of multiple series of documents, including national standards, user guides, and technical reports. It is anticipated that the testing, evaluation, and research processes will take several years to complete; therefore, the National Institute of Justice has developed this initial guide for the emergency first responder community in order to facilitate their evaluation and purchase of decontamination equipment.

In conjunction with this program, additional guides, as well as other documents, are being issued in the areas of chemical agent and toxic industrial material detection equipment, biological agent detection equipment, personal protective equipment, medical kits and equipment, and communications equipment used in conjunction with protective clothing and respiratory equipment.

The information contained in this guide has been obtained through literature searches and market surveys. The vendors were contacted multiple times during the preparation of this guide to ensure data accuracy. In addition, the information is supplemented with test data obtained from other sources (e.g., Department of Defense) if available. It should also be noted that the purpose of this guide is not to provide recommendations but rather to serve as a means to provide information to the reader to compare and contrast commercially available decontamination equipment. *Reference herein to any specific commercial products, processes, or services by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government. The information and statements contained in this guide shall not be used for the purposes of advertising, nor to imply the endorsement or recommendation of the United States Government.*

With respect to information provided in this guide, neither the United States Government nor any of its employees make any warranty, expressed or implied, including but not limited to the warranties of merchantability and fitness for a particular purpose. Further, neither the United States Government nor any of its employees assume any legal liability or responsibility for the

accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed.

Technical comments, suggestions, and product updates are encouraged from interested parties. They may be addressed to the Office of Law Enforcement Standards, National Institute of Standards and Technology, 100 Bureau Drive, Stop 8102, Gaithersburg, MD 20899–8102. It is anticipated that this guide will be updated periodically.

Questions relating to the specific devices included in this document should be addressed directly to the proponent agencies or the equipment manufacturers. Contact information for each equipment item included in this guide can be found in Volume II of this guide.

1. INTRODUCTION

This guide includes information that is intended to assist the emergency first responder community select chemical agent, biological agent, and toxic industrial material decontamination techniques and equipment for different applications. It includes a thorough market survey of decontamination equipment known to the authors as of September 2000. Brief technical discussions are presented that consider the principles of operation of several pieces of equipment. These may be ignored by readers who find them too technical, while those wanting additional information can obtain it from the extensive list of references that is included in appendix B.

This guide describes equipment suitable for decontamination of personnel, equipment, and facilities, and it offers effectiveness in qualitative terms. It does not address detection methods or protocols for quantitatively determining decontamination effectiveness, standards for release of equipment of facilities for unrestricted use following exposure to a chemical agent (CA), biological agent (BA), or toxic industrial material (TIM) after decontamination, or who is authorized or will take responsibility for making that determination. For the remainder of this guide when chemical agent and TIM decontamination are referred to collectively, they will be referred to as chemical decontamination.

The primary purpose of this guide is to provide emergency first responders with information that should aid them in the selection and utilization of chemical and/or biological (CB) decontamination equipment. The guide is more practical than technical and provides information on a variety of factors that can be considered when purchasing decontamination equipment: functional application, capacity/throughput, and effectiveness.

Due to the high number of CB decontamination equipment items identified in this guide, the guide is separated into two volumes. Volume I represents the actual guide. Volume II serves as a supplement to Volume I and contains the CB decontamination equipment data sheets only.

This guide contains information that should aid emergency first responders in the selection and utilization of CB decontamination equipment. Readers finding this material too technical can omit this information while still making use of the rest of the guide, and readers desiring more technical detail can obtain it from the references listed in appendix B and the data sheets provided in Volume II. Volume I is divided into several sections. Section 2 provides an introduction to chemical agents, TIMs, and biological agents. Specifically, it discusses CB agents by providing overviews, physical and chemical properties, routes of entry, and symptoms. It also discusses the 98 TIMs that are considered in this guide. Section 3 presents an overview to CB decontamination. Section 4 presents an overview of the identified decontaminants. Section 5 presents an overview of the initiatives taken by emergency first responders for CB decontamination. Section 6 discusses various characteristics and performance parameters that are used to evaluate decontamination equipment in this guide. These characteristics and performance parameters are referred to as selection factors in the remainder of this guide. Thirteen selection factors have been identified. These factors were compiled by a panel of experienced scientists and engineers with multiple years of experience in chemical and biological decontamination, domestic preparedness, and identification of emergency first responder needs.

The factors have also been shared with the emergency responder community to get their thoughts and comments. Section 7 presents several tables that allow the reader to compare and contrast the different decontamination equipment utilizing the 13 selection factors.

Eight appendices are included within this guide. Appendix A lists questions that could assist emergency first responders selecting decontamination equipment. Appendix B lists the documents that are referenced in this guide. Appendix C contains a listing of commercially available decontamination shelters. Appendix D provides an example of a decontamination equipment trailer. Appendix E provides an index of the decontaminant data sheets. Appendix F provides chemical decontaminant data sheets. Appendix G includes a letter from the Environmental Protection Agency (EPA) that addresses handling of hazardous runoff from decontamination operations and liabilities. Appendix H is an EPA publication regarding the first responders' environmental liability due to decontamination runoff.

2. DESCRIPTION OF CHEMICAL AGENTS, TOXIC INDUSTRIAL MATERIALS, AND BIOLOGICAL AGENTS

This section describes chemical agents (CAs), toxic industrial materials (TIMs), and biological agents (BAs). Section 2.1 discusses chemical agents, section 2.2 discusses TIMs, and section 2.3 discusses biological agents.

2.1 Chemical Agents

Chemical agents are chemical substances that are intended for use in warfare or terrorist activities to kill, seriously injure, or seriously incapacitate people through their physiological effects. A chemical agent attacks the organs of the human body in such a way that it prevents those organs from functioning normally. The results are usually disabling or even fatal.

The most common chemical agents are the nerve agents, GA (Tabun), GB (Sarin), GD (Soman), GF, and VX; the blister agents, HD (sulfur mustard) and HN (nitrogen mustard); and the arsenical vesicants, L (Lewisite). Other toxic chemicals such as hydrogen cyanide (characterized as a chemical blood agent by the military) are included as TIMs under section 2.2 of this guide. There are also toxic chemicals derived from living organisms, generically termed toxins. Toxins are included under section 2.5 of this guide.

2.1.1 Nerve Agents

This section provides an overview of nerve agents. A discussion of their physical and chemical properties, their routes of entry, and descriptions of symptoms are also provided.

2.1.1.1 Overview

Among lethal chemical agents, nerve agents have had an entirely dominant role since World War II. Nerve agents acquired their name because they affect the transmission of impulses in the nervous system. All nerve agents belong to the chemical group of organo-phosphorus compounds; many common herbicides and pesticides also belong to this chemical group. Nerve agents are stable, easily dispersed, highly toxic, and have rapid effects when absorbed both through the skin and the respiratory system. Nerve agents can be manufactured by means of fairly simple chemical techniques. The raw materials are inexpensive, but some are subject to the controls of the Chemical Weapons Convention and the Australia Group Agreement.

2.1.1.2 Physical and Chemical Properties

The nerve agents considered in this guide are:

- GA: A low volatility persistent chemical agent that is taken up through skin contact and inhalation of the substance as a gas or aerosol. Volatility refers to a substance's ability to become a vapor at relatively low temperatures. A highly volatile

(nonpersistent) substance poses a greater respiratory hazard than a less volatile (persistent) substance.

- GB: A volatile nonpersistent chemical agent mainly taken up through inhalation.
- GD: A moderately volatile chemical agent that can be taken up by inhalation or skin contact.
- GF: A low volatility persistent chemical agent that is taken up through skin contact and inhalation of the substance either as a gas or aerosol.
- VX: A low volatility persistent chemical agent that can remain on material, equipment, and terrain for long periods. Uptake is mainly through the skin but also through inhalation of the substance as a gas, aerosol, or contaminated dust.

Nerve agents in the pure state are colorless liquids. Their volatility varies widely. The consistency of VX may be likened to motor oil and is therefore classified as belonging to the group of persistent chemical agents. VX effect is mainly through direct contact with the skin. GB is at the opposite extreme; being an easily volatile liquid (comparable with water), it is mainly taken up through the respiratory organs. The volatilities of GD, GA, and GF are between those of GB and VX. Table 2-1 lists the common nerve agents and some of their physical and chemical properties. Water is included in the table as a reference point for the nerve agents.

Table 2–1. Physical and chemical properties of common nerve agents

Property	GA	GB	GD	GF	VX	Water
Molecular Weight	162.3	140.1	182.2	180.2	267.4	18
Density, g/cm^3*	1.073	1.089	1.022	1.120	1.008	1
Boiling point, ^{o}F	464	316	388	462	568	212
Melting point, ^{o}F	18	-69	-44	-22	< -60	32
Vapor pressure, mm Hg *	0.07	2.9	0.4	0.06	0.0007	23.756
Volatility, mg/m^3 *	610	22000	3900	600	10.5	23010
Solubility in water, % *	10	Miscible with water	2	~2	Slightly	NA

*at 77 ^{o}F

2.1.1.3 Route of Entry

Nerve agents, either as a gas, aerosol, or liquid, enter the body through inhalation or through the skin. Poisoning may also occur through consumption of liquids or foods contaminated with nerve agents.

The route of entry also influences the symptoms developed and, to some extent, the sequence of the different symptoms. Generally, the poisoning works most rapidly when the agent is absorbed through the respiratory system, rather than other routes, because the lungs contain numerous blood vessels and the inhaled nerve agent can quickly diffuse into the blood circulation and thus reach the target organs. Among these organs, the respiratory system is one of the most

important. If a person is exposed to a high concentration of nerve agent (e.g., 200 mg sarin/m^3), death may occur within a couple of minutes.

The poisoning works slower when the agent is absorbed through the skin. Since nerve agents are somewhat fat-soluble, they can easily penetrate the outer layers of the skin, but it takes longer for the poison to reach the deeper blood vessels. Consequently, the first symptoms do not occur until 20 min to 30 min after the initial exposure, but subsequently, the poisoning process may be rapid if the total dose of nerve agent is high.

2.1.1.4 Symptoms

When exposed to a low dose of nerve agent, sufficient to cause minor poisoning, the victim experiences characteristic symptoms such as increased production of saliva, a runny nose, and a feeling of pressure on the chest. The pupil of the eye becomes contracted (miosis), which impairs night-vision. In addition, the capacity of the eye to change focal length is reduced, and short-range vision deteriorates causing the victim to feel pain when trying to focus on nearby objects. This is accompanied by a headache. Less specific symptoms are tiredness, slurred speech, hallucinations, and nausea.

Exposure to a higher dose leads to more dramatic developments, and symptoms are more pronounced. Bronchoconstriction and secretion of mucus in the respiratory system leads to difficulty in breathing and to coughing. Discomfort in the gastrointestinal tract may develop into cramping and vomiting, and there may be involuntary discharge of urine and defecation. There may be excessive salivating, tearing, and sweating. If the poisoning is moderate, typical symptoms affecting the skeletal muscles may be muscular weakness, local tremors, or convulsions.

When exposed to a high dose of nerve agent, the muscular symptoms are more pronounced and the victim may suffer convulsions and lose consciousness. The poisoning process may be so rapid that symptoms mentioned earlier may never have time to develop.

Nerve agents affect the respiratory muscles causing muscular paralysis. Nerve agents also affect the respiratory center of the central nervous system. The combination of these two effects is the direct cause of death. Consequently, death caused by nerve agents is similar to death by suffocation.

2.1.2 Blister Agents (Vesicants)

This section provides an overview of blister agents. A discussion of their physical and chemical properties, their routes of entry, and descriptions of symptoms is also provided.

2.1.2.1 Overview

There are two major families of blister agents: sulfur mustard (HD) and nitrogen mustard (HN), and the arsenical agent: Lewisite (L). All blister agents are persistent and may be employed in the form of colorless gases and liquids. They burn and blister the skin or any other part of the

body they contact. Blister agents are likely to be used to produce casualties rather than to kill, although exposure to such agents can be fatal.

2.1.2.2 Physical and Chemical Properties

In its pure state, mustard agent is colorless and almost odorless. It earned its name as a result of an early production method that resulted in an impure product with a mustard-like odor. Mustard agent is also claimed to have a characteristic odor similar to rotten onions. However, the sense of smell is dulled after only a few breaths so that the smell can no longer be distinguished. In addition, mustard agent can cause injury to the respiratory system in concentrations that are so low that the human sense of smell cannot distinguish them.

At room temperature, mustard agent is a liquid with low volatility and is very stable during storage. Mustard agent can easily be dissolved in most organic solvents but has negligible solubility in water. In aqueous solutions, mustard agent decomposes into nonpoisonous products by means of hydrolysis but since only dissolved mustard agent reacts, the decomposition proceeds very slowly. Oxidants such as chloramines (see 4.2.1, Oxidizing Agents, for chloramine action), however, react violently with mustard agent, forming nonpoisonous oxidation products. Consequently, these substances are used for the decontamination of mustard agent.

Arsenical vesicants are not as common or as stable as the sulfur or nitrogen mustards. All arsenical vesicants are colorless to brown liquids. They are more volatile than mustard and have fruity to geranium-like odors. These types of vesicants are much more dangerous as liquids than as vapors. Absorption of either vapor or liquid through the skin in adequate dosage may lead to systemic intoxication or death. The physical and chemical properties of the most common blister agents are listed in table 2–2. Water is included in the table as a reference point for the blister agents (see table 2–2).

Table 2–2. Physical and chemical properties of common blister agents

Property	HD	HN-1	HN-2	HN-3	L	Water
Molecular Weight	159.1	170.1	156.1	204.5	207.4	18
Density, g/cm^3	1.27 at 68 °F	1.09 at 77 °F	1.15 at 68 °F	1.24 at 77 °F	1.89 at 68 °F	1 at 77 °F
Boiling point, °F	421	381	167 at 15 mm Hg	493	374	212
Freezing point, °F	58	-61.2	-85	-26.7	64.4 to 32.18	32
Vapor pressure, mm Hg	0.072 at 68 °F	0.24 at 77 °F	0.29 at 68 °F	0.0109 at 77 °F	0.394 at 68 °F	23.756 at 77 °F
Volatility, mg/m^3	610 at 68 °F	1520 at 68 °F	3580 at 77 °F	121 at 77 °F	4480 at 68 °F	23010 at 77 °F
Solubility in water, %	<1 %	Sparingly	Sparingly	Insoluble	Insoluble	NA

2.1.2.3 Route of Entry

Most blister agents are relatively persistent and are readily absorbed by all parts of the body. Poisoning may also occur through consumption of liquids or foods contaminated with blister agents. These agents cause inflammation, blisters, and general destruction of tissues. In the form of gas or liquid, mustard agent attacks the skin, eyes, lungs, and gastrointestinal tract. Internal organs, mainly blood-generating organs (e.g., marrow, spleen, and lymphatic tissue), may also be injured as a result of mustard agent being taken up through the skin or lungs and transported into the body. Since mustard agent gives no immediate symptoms upon contact, a delay of between 2 h and 24 h may occur before pain is felt and the victim becomes aware of what has happened. By then, cell damage has already occurred. The delayed effect is a characteristic of mustard agent.

In general, vesicants can penetrate the skin by contact with either liquid or vapor. The latent period for the effects from mustard is usually several hours (the onset of symptoms from vapors is 4 h to 6 h and the onset of symptoms from skin exposure is 2 h to 48 h). There is no latent period for exposure to Lewisite.

2.1.2.4 Symptoms

Mild symptoms of mustard agent poisoning may include aching eyes with excessive tearing, inflammation of the skin, irritation of the mucous membranes, hoarseness, coughing, and sneezing. Normally, these injuries do not require medical treatment.

Severe injuries that are incapacitating and require medical care may involve eye injuries with loss of sight, the formation of blisters on the skin, nausea, vomiting, and diarrhea together with severe difficulty in breathing. Severe damage to the eye may lead to the total loss of vision.

The most pronounced effects on inner organs are injury to the bone marrow, spleen, and lymphatic tissue. This may cause a drastic reduction in the number of white blood cells 5 d to 10 d after exposure; a condition very similar to that after exposure to radiation. This reduction of the immune defense will complicate the already large risk of infection in people with severe skin and lung injuries.

The most common cause of death as a result of mustard agent poisoning is complications after lung injury caused by inhalation of mustard agent. Most of the chronic and late effects from mustard agent poisoning are also caused by lung injuries.

2.2 Toxic Industrial Materials (TIMs)

This section provides a general overview of TIMs as well as a list of the specific TIMs considered in this guide. Since the chemistry of TIMs is so varied, it is not feasible to discuss specific routes of entry and descriptions of symptoms. Several documents, including *2000 Emergency Response Guidebook (A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident),* provide more detailed information about TIMs (see app. B).

TIMs are chemicals other than chemical warfare agents that have harmful effects on humans. TIMs, often referred to as toxic industrial chemicals, or TICs, are used in a variety of settings such as manufacturing facilities, maintenance areas, and general storage areas. While exposure to some of these chemicals may not be immediately dangerous to life and health (IDLH), these compounds may have extremely serious effects on an individual's health after multiple low-level exposures.

2.2.1 General

A TIM is a *specific type* of industrial chemical, i.e., one that has a LCt_{50} value (lethal concentration of a chemical vapor or aerosol for 50 % of the population multiplied by exposure time) less than 100000 mg/min/m^3 in any mammalian species and is produced in quantities exceeding 30 tons per year at one production facility. Although they are not as lethal as the highly toxic nerve agents, their ability to make a significant impact on the populace is assumed to be more related to the amount of chemical a terrorist can employ on the target(s) and less related to their lethality. None of these compounds are as highly toxic as the nerve agents, but they are produced in very large quantities (multi-ton) and are readily available; therefore, they pose a far greater threat than chemical agents. For instance, sulfuric acid is not as lethal as the nerve agents, but it is easier to disseminate large quantities of sulfuric acid because large amounts of it are manufactured and transported everyday. It is assumed that a balance is struck between the lethality of a material and the amount of materials produced worldwide. Materials such as the nerve agents are so lethal as to be in a special class of chemicals.

Since TIMs are less lethal than the highly toxic nerve agents, it is more difficult to determine how to rank their potential for use by a terrorist. Physical and chemical properties for TIMs such as ammonia, chlorine, cyanogen chloride, and hydrogen cyanide are presented in table 2–3. Water is included in the table as a reference point for the TIMs. The physical and chemical

properties for the remaining TIMs identified in this guide can be found in International *Task Force 25: Hazard From Industrial Chemicals Final Report, April 1998* (see app. B).

Table 2–3. Physical and chemical properties of TIMs

Property	Ammonia	Chlorine	Cyanogen Chloride	Hydrogen Cyanide	Water
Molecular weight	17.03	70.9	61.48	27.02	18
Density, g/cm^3	0.00077 at 77 °F	3.214 at 77 °F	1.18 at 68 °F	0.990 at 68 °F	1 at 77 °F
Boiling point, °F	-28	-30	55	78	212
Freezing point, °F	-108	-150	20	8	32
Vapor pressure, mm Hg at 77 °F	7408	5643	1000	742	23.756
Volatility, mg/m^3	6782064 at 77 °F	21508124 at 77 °F	2600000 at 68 °F	1080000 at 77 °F	23010 at 77 °F
Solubility in water, %	89.9	1.5	Slightly	Highly soluble	NA

2.2.2 TIM Rankings

TIMs are ranked into one of three categories that indicate their relative importance and assist in hazard assessment. Table 2–4 lists the TIMs with respect to their hazard index ranking (high, medium, or low hazard).[4]

2.2.2.1 High Hazard

High hazard indicates a widely produced, stored, or transported TIM, that has high toxicity and is easily vaporized.

2.2.2.2 Medium Hazard

Medium hazard indicates a TIM, which may rank high in some categories but lower in others such as number of producers, physical state, or toxicity.

2.2.2.3 Low Hazard

A low hazard overall ranking indicates that this TIM is not likely to be a hazard unless specific operational factors indicate otherwise.

[4] Summary of the Final Report of the International Task Force 25 Hazard from Industrial Chemicals, 15 April 1999.

Table 2–4. TIMs listed by hazard index

High	Medium	Low
Ammonia	Acetone cyanohydrin	Allyl isothiocyanate
Arsine	Acrolein	Arsenic trichloride
Boron trichloride	Acrylonitrile	Bromine
Boron trifluoride	Allyl alcohol	Bromine chloride
Carbon disulfide	Allylamine	Bromine pentafluoride
Chlorine	Allyl chlorocarbonate	Bromine trifluoride
Diborane	Boron tribromide	Carbonyl fluoride
Ethylene oxide	Carbon monoxide	Chlorine pentafluoride
Fluorine	Carbonyl sulfide	Chlorine trifluoride
Formaldehyde	Chloroacetone	Chloroacetaldehyde
Hydrogen bromide	Chloroacetonitrile	Chloroacetyl chloride
Hydrogen chloride	Chlorosulfonic acid	Crotonaldehyde
Hydrogen cyanide	Diketene	Cyanogen chloride
Hydrogen fluoride	1,2-Dimethylhydrazine	Dimethyl sulfate
Hydrogen sulfide	Ethylene dibromide	Diphenylmethane-4,4'-diisocyanate
Nitric acid, fuming	Hydrogen selenide	Ethyl chloroformate
Phosgene	Methanesulfonyl chloride	Ethyl chlorothioformate
Phosphorus trichloride	Methyl bromide	Ethyl phosphonothioic dichloride
Sulfur dioxide	Methyl chloroformate	Ethyl phosphonic dichloride
Sulfuric acid	Methyl chlorosilane	Ethyleneimine
Tungsten hexafluoride	Methyl hydrazine	Hexachlorocyclopentadiene
	Methyl isocyanate	Hydrogen iodide
	Methyl mercaptan	Iron pentacarbonyl
	Nitrogen dioxide	Isobutyl chloroformate
	Phosphine	Isopropyl chloroformate
	Phosphorus oxychloride	Isopropyl isocyanate
	Phosphorus pentafluoride	n-Butyl chloroformate
	Selenium hexafluoride	n-Butyl isocyanate
	Silicon tetrafluoride	Nitric oxide
	Stibine	n-Propyl chloroformate
	Sulfur trioxide	Parathion
	Sulfuryl chloride	Perchloromethyl mercaptan
	Sulfuryl fluoride	sec-Butyl chloroformate
	Tellurium hexafluoride	tert-Butyl isocyanate
	n-Octyl mercaptan	Tetraethyl lead
	Titanium tetrachloride	Tetraethyl pyroposphate
	Trichloroacetyl chloride	Tetramethyl lead
	Trifluoroacetyl chloride	Toluene 2,4-diisocyanate
		Toluene 2,6-diisocyanate

2.3 Biological Agents

This section provides a description of the biological agents likely to be used in a terrorist attack. There are four categories under discussion: bacterial agents (sec. 2.3.1), viral agents (sec. 2.3.2), rickettsiae (sec. 2.3.3), and biological toxins (sec. 2.3.4).

2.3.1 Bacterial Agents

Bacteria are small, single-celled organisms, most of which can be grown on solid or liquid culture media. Under special circumstances, some types of bacteria can transform into spores that are more resistant to cold, heat, drying, chemicals, and radiation than the bacterium itself. Most bacteria do not cause disease in human beings but those that do cause disease by two differing mechanisms: by invading the tissues or by producing poisons (toxins). Many bacteria, such as anthrax, have properties that make them attractive as potential warfare agents:

- Retained potency during growth and processing to the end product (biological weapon).
- Long "shelf-life."
- Low biological decay as an aerosol.

Other bacteria require stabilizers to improve their potential for use as biological weapons. Table 2–5 lists some of the common bacterial agents along with possible methods of dissemination, incubation period, symptoms, and treatment.

2.3.2 Viral Agents

Viruses are the simplest type of microorganism and consist of a nucleocapsid protein coat containing genetic material, either RNA or DNA. Because viruses lack a system for their own metabolism, they require living hosts (cells of an infected organism) for replication. As biological agents, they are attractive because many do not respond to antibiotics. However, their incubation periods are normally longer than for other biological agents, so incapacitation of victims may be delayed. Table 2–6 lists the common viral agents along with possible methods of dissemination, incubation period, symptoms, and treatment.

2.3.3 Rickettsiae

Rickettsiae are obligate intracellular bacteria that are intermediate in size between most bacteria and viruses and possess certain characteristics common to both bacteria and viruses. Like bacteria, they have metabolic enzymes and cell membranes, use oxygen, and are susceptible to broad-spectrum antibiotics, but like viruses, they grow only in living cells. Most rickettsiae can be spread only through the bite of infected insects and are not spread through human contact. Table 2–7 lists the common rickettsiae along with possible methods of dissemination, incubation periods, symptoms, and treatment.

2.3.4 Biological Toxins

Biological toxins are poisons produced by living organisms. It is the poison and not the organism that produces harmful effects in man. A toxin typically develops naturally in a host organism (for example, saxitoxin is produced by marine algae); however, genetically altered and/or synthetically manufactured toxins have been produced in a laboratory environment. Biological toxins are most similar to chemical agents in their dissemination and effectiveness. Table 2–8 lists the common biological toxins along with possible methods of dissemination, incubation period, symptoms, and treatment.

Table 2-5. Bacterial agents

Biological Agent/Disease	Anthrax	Brucellosis	E. coli serotype (O157:H7)	Tularemia	Cholera
Likely Method of Dissemination	1. Spores in aerosol 2. Sabotage (food)	1. Aerosol 2. Sabotage (food)	Water and food supply contamination	1. Aerosol 2. Rabbits or ticks	1. Sabotage (food and water) 2. Aerosol
Transmissible Person to Person	No (except cutaneous)	Unknown	Unknown, evidence passed person-to-person in day-care or nursing homes	No	Rare
Incubation Period	1 d to 43 d	1 wk to 3 wk, sometimes months	Unknown	2 d to 10 d	3 d to 5 d
Duration of Illness	3 d to 5 d (usually fatal)	Unknown	5 d to 10 d (most cases)	>2 wk	>1 wk
Lethality	Contact or cutaneous anthrax: fatality rate of 5 % to 20 % Inhalational anthrax: after symptoms appear almost always fatal, regardless of treatment	Low	0 % to 15 % if develop hemolytic uremic syndrome (HUS); 5 % if develop thrombotic thrombocytopenic purpura (TTP)	Moderate if left untreated	Low (<1 %) with treatment; high (>50 %) without
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	Currently no human data	Vaccine under evaluation	No vaccine	No commercially available vaccine	No data on aerosol
Symptoms and Effects	Flu-like, upper-respiratory distress; fever and shock in 3 d to 5 d, followed by death	Irregular prolonged fever, profuse sweating, chills, joint and muscle pain, persistent fatigue	Gastrointestinal (diarrhea, vomiting) dehydration; in severe cases, cardiac arrest and death, HUS, or TTP	Chills, sustained fever, prostration, tendency for pneumonia, enlarged, painful lymph nodes, headache, malaise, anorexia, nonproductive cough	Sudden onset with nausea, vomiting, diarrhea, rapid dehydration, toxemia and collapse
Treatment	Vaccine available for cutaneous, possibly inhalation, anthrax. Cutaneous anthrax responds to antibiotics (penicillin, terramycin, chloromycetin), sulfadiazine and immune serum. Pulmonary (inhaled) anthrax responds to immune serum in initial stages but is little use after disease is well established. Intestinal, same as for pulmonary	Antibiotics	Antibiotics available; most recover without antibiotics within 5 d to 10 d; do not use antidiarrheal agents	Vaccination using live attenuated organisms reduces severity and transmittability; antibiotics (streptomycin, aureomycin, chloromycetin, doxycycline, tetracycline, and chloramphenical)	Replenish fluids and electrolytes; antibiotics (tetracycline, ciprofloxicin, and erythromycin) enhance effectiveness of rehydration and reduce organism in body
Potential as Biological Agent	Iraqi and USSR biological programs worked to develop anthrax as a bio-weapon	Unknown	Unknown	High, if delivered via aerosol form (highly infectious, 90 % to 100 %)	Not appropriate for aerosol delivery

Table 2-5. Bacterial agents-Continued

Biological Agent/Disease	Diphtheria	Glanders	Melioidosis	Plague (Bubonic and Pneumonic)	Typhoid Fever
Likely Method of Dissemination	Unknown	1. Aerosol 2. Cutaneous	1. Food contamination (rodent feces) 2. Inhalation 3. Insect bites 4. Direct contact with infected animals	1. Infected fleas (Bubonic and Pneumonic) 2. Aerosol (Pneumonic)	1. Contact with infected person 2. Contact with contaminated substances
Transmissible Person to Person	High	High	No	High (Pneumonic)	High
Incubation Period	2 d to 5 d	3 d to 5 d	Days	1 d to 3 d	7 d to 14 d
Duration of Illness	Unknown	Unknown	4 d to 20 d	1 d to 6 d (usually fatal)	Unknown
Lethality	5 % to 10 % fatality	50 % to 70 %	Variable	5 % to 10 % if treated Bubonic: 30 % to 75 % if untreated Pneumonic: 95 % if untreated	<1 % if treated; 10 % to 14 % if untreated
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	DPT vaccine 85 % effective; booster recommended every 10 yr	No vaccine	No vaccine	Vaccine not available	Oral vaccine (Vivotif) and single dose injectable vaccine (capsular polysaccharide antigen). Both vaccines are equally effective and offer 65 % to 75% protection against the disease.
Symptoms and Effects	Local infection usually in respiratory passages; delay in treatment can cause damage to heart, kidneys, and central nervous system	Skin lesions, ulcers in skin, mucous membranes, and viscera; if inhaled, upper respiratory tract involvement	Cough, fever, chills, muscle/joint pain, nausea, and vomiting; progressing to death	Enlarged lymph nodes in groin; septicemic (spleen, lungs, meninges affected)	Prolonged fever, lymph tissue involvement; ulceration of intestines; enlargement of spleen; rose-colored spots on skin; constipation or diarrhea
Treatment	Antitoxin extremely effective; antibiotic (penicillin) shortens the duration of illness	Drug therapy (streptomycin and sulfadiazine) is somewhat effective	Antibiotics (doxycycline, chlorothenicol, tetracycline), and sulfadiazine	Doxycycline (100 mg 2x/d for 7 d); ciprofloxicin also effective	Antibiotics (amoxicillin or cotrimoxazole) shorten period of communicability and cure disease rapidly
Potential as Biological Agent	Very low—symptoms not severe enough to incapacitate; rare cases of severe infection	Unknown	Moderate—rare disease, no vaccine available	High—highly infectious, particularly in pneumonic (aerosol) form; lack of stability and loss of virulence complicate its use	Not likely to be deployed via aerosol; more likely for covert contamination of water or food.

Table 2- 6. Viral agents

Biological Agent/Disease	Marburg Virus	Junin Virus	Rift Valley Fever Virus	Smallpox	Venezuelan Equine Encephalitis
Likely Method of Dissemination	Aerosol	Epidemiology not known	Mosquito-borne; in biological scenario, aerosols or droplets	Aerosol	1. Aerosol 2. Infected vectors
Transmissible Person to Person	Unknown	Unknown	Unknown	High	No
Incubation Period	5 d to 7 d	7 d to 16 d	2 d to 5 d	10 d to 12 d	1 d to 6 d
Duration of Illness	Unknown	16 d	2 d to 5 d	4 wk	Days to weeks
Lethality	25 %	18 %	<1 %	20 % to 40 % (Viriole major) <1 % (Viriole minor)	1 % to 60 %
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	No vaccine	No vaccine	Inactivated vaccine available in limited quantities	Vaccine protects against infection within 3 d to 5 d of exposure	Experimental only: TC-83 protects against 30 LD_{50}s to 500 LD_{50}s in hamsters
Symptoms and Effects	Sudden onset of fever, malaise, muscle pain, headache and conjunctivitis, followed by sore throat, vomiting, diarrhea, rash, and both internal and external bleeding. (begins 5th day) Liver function may be abnormal and platelet function may be impaired.	Hemorrhagic syndrome, chills, sweating, exhaustion and stupor	Febrile illness, sometimes abdominal tenderness; rarely shock, ocular problems	Sudden onset of fever, headache, backache, vomiting, marked prostration, and delirium; small blisters form crusts which fall off 10 d to 40 d after first lesions appear; opportunistic infection	Sudden illness with malaise, spiking fevers, rigors, severe headache, photophobia and myalgias
Treatment	No specific treatment exists. Severe cases require intensive supportive care, as patients are frequently dehydrated and in need of intravenous fluids.	No specific therapy; supportive therapy essential	No studies, but IV ribavirin (30 mg/kg/ 6 h for 4 d, then 7.5 mg/kg/8 h for 6 d) should be effective	Vaccinia immune globulin (VIG), and supportive therapy	Supportive treatments only
Potential as Biological Agent	High—actually weaponized by former Soviet Union biological program	Unknown	Difficulties with mosquitos as vectors	Possible, especially since routine smallpox vaccination programs have been eliminated world-wide (part of USSR offense bioprogram)	High—former US and USSR offensive biological programs weaponized both liquid and dry forms for aerosol distribution.

Table 2-6. Viral agents-Continued

Biological Agent/Disease	Yellow Fever Virus	Dengue Fever Virus	Ebola Virus	Congo-Crimean Hemorrhagic Fever Virus
Likely Method of Dissemination	Mosquito-borne	Mosquito-borne	1. Direct contact 2. Aerosol (BA)	Unknown
Transmissible Person to Person	No	No	Moderate	Yes
Incubation Period	3 d to 6 d	3 d to 15 d	4 d to 16 d	7 d to 12 d
Duration of Illness	2 weeks	1 week	Death between 7 d to 16 d	9 d to 12 d
Lethality	10 % to 20 % death in severe cases or full recovery after 2 d to 3 d	5 % average case fatality by producing shock and hemorrhage, leading to death	High for Zaire strain; moderate with Sudan	15 % to 20 %
Vaccine Efficacy (for aerosol exposure) /Antitoxin	Vaccine available; confers immunity for 10 yr +	Vaccine available	No vaccine	No vaccine available; prophylactic ribavirin may be effective
Symptoms and Effects	Sudden onset of chills, fever, prostration, aches, muscular pain, congestion, severe gastrointestinal disturbances, liver damage and jaundice; hemorrhage from skin and gums	Sudden onset of fever, chills, intense headache, pain behind eyes, joint and muscle pain, exhaustion and prostration	Mild febrile illness, then vomiting, diarrhea, rash, kidney and liver failure, internal and external hemorrhage (begins 5th day), and petechiae	Fever, easy bleeding, petechiae, hypotension and shock; flushing of face and chest, edema, vomiting, diarrhea
Treatment	No specific treatment; supportive treatment (bed rest and fluids) for even the mildest cases	No specific therapy; supportive therapy essential	No specific therapy; supportive therapy essential	No specific treatment
Potential as Biological Agent	High, if efficient dissemination device is employed	Unknown	Former Soviet Union	Unknown

Table 2-7. Rickettsiae

Biological Agent/Disease	Endemic Typhus	Epidemic Typhus	Q Fever	Rocky Mountain Spotted Fever
Likely Method of Dissemination	1. Contaminated feces 2. Infected insect Larvae 3. Rat or flea bites	1. Contaminated feces 2. Infected insect larvae	1. Sabotage (food supply) 2. Aerosol	Infected wood ticks
Transmissible Person to Person	No	No	Rare	No
Incubation Period	6 d to 14 d	6 d to 15 d	14 d to 26 d	3 d to 14 d
Duration of Illness	Unknown	Unknown	Weeks	Unknown
Lethality	1 %, increasing in people >50 yr old	10 % to 40 % untreated; increases with age	Very low	15 % to 20 % untreated, (higher in adults); treated—death rare with specific therapy (tetracycline or chloramphenicol)
Vaccine Efficacy (for aerosol exposure) /Antitoxin	Unknown	Vaccine confers protection of uncertain duration	94 % protection against 3500 LD_{50}s in guinea pigs	No vaccine
Symptoms and Effects	Sudden onset of headache, chills, prostration, fever, pain; maculae eruption on 5^{th} day to 6^{th} day on upper body, spreading to all but palms, soles, or face, but milder than epidemic form	Sudden onset of headache, chills, prostration, fever, pain; maculae eruption on 5^{th} day to 6^{th} day on upper body, spreading to all but palms, soles, or face	Mild symptoms (chills, headaches, fever, chest pains, perspiration, loss of appetite)	Fever and joint pain, muscular pain; skin rash that spreads rapidly from ankles and wrists to legs, arms, and chest; aversion to light
Treatment	Antibiotics (tetracycline and chloramphenicol); supportive treatment and prevention of secondary infections	Antibiotics (tetracycline and chloramphenicol); supportive treatment and prevention of secondary infections	Tetracycline (500 mg/ 6 h, 5 d to 7 d) or doxycycline (100 mg/ 12 h, 5 d to 7 d) also, comb. Erthyromycin (500 mg/6 h) and rifampin (600 mg/d).	Antibiotics—tetracycline or chloramphenicol
Potential as Biological Agent	Uncertain—broad range of incubation (6 d to 14 d) period could cause infection of force deploying biological agent	Uncertain—broad range of incubation (6 d to 14 d) period could cause infection of force deploying biological agent	Highly infectious, is delivered in aerosol form. Dried agent is very stable; stable in aerosol form.	Unknown

Table 2-8. Biological toxins

Biological Agent/Disease	Botulinum Toxin	Staphylococcal enterotoxin B	Tricothecene mycotoxins	Ricin (Isolated from Castor Beans)	Saxitoxin
Likely Method of Dissemination	1. Aerosol 2. Sabotage (food & water)	1. Sabotage (food supply) 2. Aerosol	1. Aerosol 2. Sabotage	1. Aerosol 2. Sabotage (food & water)	Contaminated shellfish; in biological scenario, inhalation or toxic projectile
Transmissible Person to Person	No	No	No	No	No
Incubation Period	Variable (hours to days)	3 h to 12 h	2 h to 4 h	Hours to days	5 min to 1 h
Duration of Illness	Death in 24 h to 72 h; lasts months if not lethal	Hours	Days to months	Days—death within 10 d to 12 d for ingestion	Death in 2h to 12 h
Lethality	5 % to 60 %, untreated <5 % treated	<1 %	Moderate	100 %, without treatment	High without respiratory support
Vaccine Efficacy (for aerosol exposure) /Antitoxin	Botulism antitoxin (IND) Prophylaxis toxoid (IND) Toxolide	No vaccine	No vaccine	No vaccine	No vaccine
Symptoms and Effects	Ptosis; weakness, dizziness, dry mouth and throat, blurred vision and diplopia, flaccid paralysis	Sudden chills, fever, headache, myalgia, nonproductive cough, nausea, vomiting and diarrhea	Skin—pain, pruritis, redness and vesicles, sloughing of epidermis; respiratory—nose and throat pain, discharge, sneezing, coughing, chest pain, hemoptysis	Weakness, fever, cough, pulmonary edema, severe respiratory distress	Light headedness, tingling of extremities, visual disturbances, memory loss, respiratory distress, death
Treatment	Antitoxin with respiratory support (ventilation)	Pain relievers and cough suppressants for mild cases; for severe cases, may need mechanical breathing and fluid replenishment	No specific antidote or therapeutic regimen is available; supportive and symptomatic care	Oxygen, plus drugs to reduce inflammation and support cardiac and circulatory functions; if ingested, empty the stomach and intestines; replace lost fluids	Induce vomiting, provide respiratory care, including artificial respiration
Potential as Biological Agent	Not very toxic via aerosol route; extremely lethal if delivered orally. Since covert poisoning is indistinguishable from natural botulism, poisoning could have limited use.	Moderate—could be used in food and limited amounts of water (for example, at salad bars); LD_{50} is sufficiently small to prevent detection	High—used in aerosol form ("yellow rain") in Laos, Kampuchea and Afghanistan (through 1981)	Has been used (1978—Markov murder); included on prohibited Schedule I chemicals list for Chemical Weapons Convention; high potential for use in aerosol form	Moderate, aerosol form is highly toxic

3. OVERVIEW OF CB DECONTAMINATION

Decontamination is defined as the process of removing or neutralizing a surface hazard resulting from a chemical and/or biological (CB) attack. This section provides an overview of CB decontamination. Section 3.1 discusses the decontamination processes that are used for CB decontamination. Section 3.2 provides an overview of CB decontamination applications (personnel, equipment, and infrastructure). Section 3.3 discusses equipment that is used to support CB decontamination operations.

3.1 Decontamination Process

A decontamination process refers to a method employed to destroy, reduce, or remove a contaminant to an acceptable level. There are several methods used to decontaminate CB agents and TIMs. These methods consist of physical, chemical, and thermal processes.

3.1.1 Physical Processes

Physical processes are used to remove CB agents and TIMs from surfaces. It should be noted that another means of decontamination would be necessary for CB detoxification. High-pressure systems, sorbents (simple inert), and solvent washes are examples of physical processes and are explained in the remainder of this section.

3.1.1.1 Sorbents (Simple Inert)

Sorbent technology uses materials that physically remove liquid chemicals from surfaces (e.g., skin). Generally, synthetic sorbents adsorb liquids, and natural sorbents absorb them. The state of the liquid after sorption depends on the type of sorbent material used.

For simple inert sorbent materials such as soil, diatomaceous earth, activated charcoal, or some commercially available sorbents (XAD–7, XAD–2), the liquid remains active in the sorbent material, making the sorbent material toxic. A commonly fielded sorbent-based system uses Fuller's Earth (sec. 4.1.3), a type of natural clay, in a mitt or package to sorb the agent. The liquid is absorbed by the Fuller's Earth, then wiped or blown off the surface removing the contamination. Since the liquid is not detoxified, the contaminated Fuller's Earth remains a toxic substance. An example of a decontamination equipment utilizing simple inert sorbents is the Decontamination Kit, Personal No. 2, Mark 1 (fig. 3–1), manufactured by Richmond Packaging Limited.

Figure 3–1. Decontamination Kit, Personal No. 2, Mark 1

3.1.1.2 Solvent Wash

The use of a solvent to remove a CB contaminant is a physical rather than a chemical process. Chemical agents are removed from a surface by washing the molecules away using water, alcohol, freon, diesel fuel, etc. In this process, the agent is diluted, but not detoxified, and there may be residues left behind in cracks, pits, joints, etc. Solvents are often applied in an open environment using pressurized sprayers such as a Hudson® sprayer, a power washer, or an aerosol sprayer. The runoff from a solvent decontamination must be collected in order to minimize the areas contaminated. Solvent wash technology can also be used in an enclosed environment to effectively decontaminate patrol car interiors, portable communications equipment, or electronic devices. In a closed system, the solvents can be manipulated by heating them or using them in conjunction with ultrasonic or supersonic sprays in order to increase their decontamination effectiveness. After a decontamination cycle, the solvents can often be recycled for further use in additional cycles before being discarded and detoxified.

3.1.1.3 High-Pressure Systems

Decontaminants, such as water and carbon dioxide, sprayed at high pressures are effectively used to physically remove chemical and biological agents from surfaces. Studies have demonstrated that chemical agents can be removed from surfaces with water pressures $\leq$ 3000 lb per square inch (psi). Removal of agents from surfaces is highly dependent upon the nature of the surfaces (i.e., surfaces which are flat and smooth can be more readily decontaminated than curved porous surfaces using water sprays). Other parameters that affect the effectiveness of water streams for decontamination are pressure, temperature, angle of attack, traverse velocity, space between traverses, standoff distance, flow volume, and jet characteristics. Additives can be added to the water to improve the water jet characteristics. Likewise, water sprayed onto personnel using showers or other low-pressure delivery systems can be used to decontaminate skin.

One example of decontamination equipment utilizing a high-pressure system is the K1-05 standard unit (fig. 3–2) manufactured by Applied Surface Technology. The K1-05 system employs high-pressure carbon dioxide to physically remove contaminates. Another example is the Karcher HDS 1200 EK high-pressure steam jet cleaner unit (fig. 3–3), manufactured by Karcher, that employs mechanical technology by disseminating high-pressure cold or hot water, steam, or dry steam to decontaminate materials.

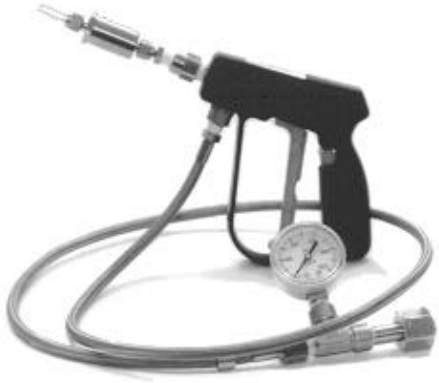

Figure 3–2. K1-05 standard unit

Figure 3–3. Karcher HDS 1200 EK high-pressure steam jet cleaner unit

3.1.2 Chemical Processes

Chemical processes involve the use of reactive or catalytic chemicals (sorbents) to neutralize CB contaminants. Another means of decontamination would be necessary for chemical agent, TIM, or biological agent removal.

A reactive sorbent first adsorbs the CB contaminate and then chemically detoxifies it. Reactive sorbents have been prepared by soaking simple sorbents in alkaline solutions, effectively "loading" the matrix with caustic material. Once sorbed into the sorbent matrix, the agent encounters the alkaline medium, reacts with it, and is destroyed. A second approach for reactive sorbents is to prepare a polymeric material with reactive groups attached to the polymeric backbone. In this case, the agent is sorbed by the polymeric matrix, encounters the reactive group, and is neutralized by it. A third approach is to use microcrystalline metal oxides such as aluminum oxide or magnesium oxide. An example of decontamination equipment utilizing reactive sorbents is the Decontamination Kit, Individual Equipment: M295, manufactured by Truetech (fig. 3–4).

Figure 3–4. Decontamination Kit, Individual Equipment: M295

Catalytic sorbents are similar to reactive sorbents in that both contain reactive sites that react with and detoxify the CB contaminants. In the case of catalytic sorbents, the reactive site is

regenerated during detoxification of the agent while, in the case of reactant sorbents, the reactive group is rendered inert after reacting with the agent. Examples of catalytic sorbents are polyoxometalates sorbed into a sorbent polymeric matrix and polymeric materials containing reactive sites that are covalently bound to the polymer chain.

3.1.3 Thermal Processes

Thermal processes remove CB contaminants through vaporization. It should be noted that another means of decontamination is necessary for agent detoxification. Examples of decontamination equipment utilizing a thermal process are the Karcher mobile field laundry CFL 60 (fig. 3–5) that both physically and thermally removes decontaminates, and the Karcher AEDA1 decontamination equipment (fig. 3–6) that employs a combination of low-temperature thermal technology and mechanical technology.

Figure 3–5. Karcher mobile field laundry CFL 60

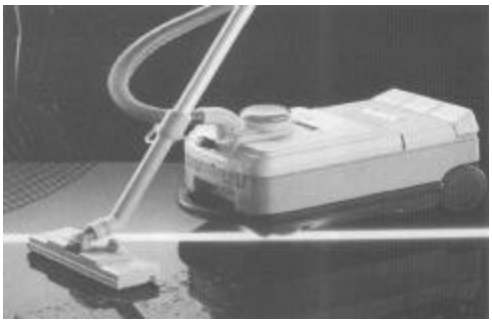

Figure 3–6. Karcher AEDA1 decontamination equipment

3.2 Decontamination Applications

The three application areas involved with CB decontamination are personnel, equipment, and infrastructure. The remainder of this section presents each application in more detail.

3.2.1 Personnel Decontamination

Personnel decontamination refers to the ability to decontaminate CB agent or TIMs from human skin and personal equipment (e.g., clothing, personal protective equipment) that may pose a direct threat to human health through direct contact. Decontamination of the skin must quickly and efficiently remove the contaminant without causing damage to the skin. Skin decontaminants can either destroy the contaminant on the skin through chemical or biological reactions or physically remove it from the skin. An example of personnel decontamination equipment is the NBC-DEWDECON-PERS Emergency Response Personnel Decontamination Kit (shown in fig. 3–7). Depending on the decontaminants used in the kit, either chemical or mechanical technologies may be employed.

Figure 3–7. NBC-DEWDECON-PERS Emergency Response Personnel Decontamination Kit

For general decontamination information the reader can refer to *Responding to A Biological or Chemical Threat: A Practical Guide* (see app. B). For information on methods and techniques utilized during mass casualty decontamination, the reader should refer to *Guidelines for Mass Casualty Decontamination During a Terrorist Chemical Agent Incident* (see app. B).

3.2.2 Equipment Decontamination

Equipment decontamination refers to the ability to decontaminate CB agent or TIMs from the exterior surfaces of equipment. This includes the decontamination of both large (e.g., vehicles) and small items (e.g., computers, communications equipment). An example of this type of equipment is the Karcher MPDS multipurpose decontamination system (shown in fig. 3–8). The MPDS is equipped with a high-pressure spray system and depending on the decontaminant that was used, either chemical or mechanical technologies are employed.

Figure 3–8. Karcher MPDS multipurpose decontamination system

3.2.3 Infrastruture Decontamination

Infrastructure decontamination involves the removal of CB agents or TIMs from large-scale items (e.g., buildings, roadways). Due to their extensive surface area, these items require special consideration during the performance of decontamination operations. An example of infrastructure decontamination equipment is the Karcher C8–DADS direct application

decontamination system (shown in fig. 3–9). This system uses both physical (removes contaminate) and chemical (neutralizes contaminant) decontamination processes.

Figure 3–9. Karcher C8–DADS direct application decontamination system

3.3 Support Equipment

This guide primarily focuses on decontamination equipment used for removing and/or neutralizing CB contamination from personnel (to include clothing), equipment, and infrastructure. However, emergency first responders should be aware that there is equipment used to support CB decontamination operations. Decontamination shelters and decontamination units (shower/dressing rooms with basins and bladders) are examples of equipment used to support decontamination operations. Decontamination shelters are used to provide protection to personnel (victims, technicians, etc.), subsequent to decontamination operations, from any remaining CB contamination. Examples of decontamination shelters are the TVI first response shelter (fig. 3–10) and the TVI Quick-E WMD command post (fig. 3–11).

Figure 3–10. TVI first response shelter

Figure 3–11. TVI Quick-E WMD command post

Portable decontamination shower units keep water contained by patented recovery bladders connected to a catch basin while the victims stand on a stool above the contaminated water. The units are available as single, double, or quad units. Examples of decontamination units are the

SC spill containment single shower stall with dressing room (fig. 3–12) and the SC spill containment single decon unit with bladder (fig. 3–13). Appendix C contains a listing of commercially available decontamination shelters.

Figure 3–12. SC spill containment single shower stall with dressing room

Figure 3–13. SC spill containment single decon unit with bladder